Torch and Crucible

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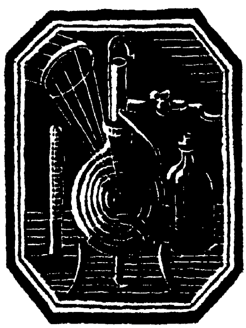
The Life and Death of Antoine Lavoisier

By Sidney J. French



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TO

ALBERT D. WHEALDON

MY FIRST TEACHER

OF CHEMISTRY

Preface

THIS book represents an attempt to fuse two images, to unite in one person the elements which made Lavoisier such a striking figure. Even without his science, Lavoisier was an outstanding man of his time; with it, he was one of the most versatile men of all time. Scientists see his place in science, historians, his place in history. A successful fusion of the two is not a simple task for either alone.

Any book written around Lavoisier must, perforce, draw heavily on the authoritative biography written in the French by Grimaux. This book is no exception. But any book which stops there can claim credit for being little more than a translation. Grimaux on the *life* of Lavoisier is authoritative, but Grimaux on the *science* of Lavoisier falls short. He passes lightly over the great controversies which arose concerning Lavoisier's scientific work, over the difficulties which Lavoisier encountered in bringing his buds to fruit, over the charges of unethical conduct, over the weaknesses of his man.

Lavoisier has been charged with getting his ideas for the great revolution in science from Black, Priestley, Cavendish and others. That he used the discoveries of these men cannot be denied. That he got the germ of his great theory from them can now be denied with real assurance, and is denied by the painstaking investigations of A. N. Meldrum, published in 1930. These findings should destroy the last shred of suspicion that Lavoisier's dream of a revolution in science originated anywhere but in his own head.

Douglas McKie in his *Antoine Lavoisier* (1935), concurs in these findings and confers the title of "Father of Modern Chem-

istry" not on Robert Boyle where a number of Englishmen have placed it, but on Antoine Lavoisier. The findings of these two Englishmen substantiate many of the claims made by Lavoisier's supporters but they do not justify the sweeping claims of Grimaux's enthusiastic pen.

That the three great English scientists, Black, Priestley and Cavendish made possible the completion of Lavoisier's dream of a revolution in science is unquestioned. They were the supporting actors in the great drama and no story of this epic in science could be complete unless their important parts were included.

For the first time in a biography of Lavoisier, the important and interesting friendship between the Lavoisier and the Du Pont families has been traced in some detail. This has been made possible largely through the use of the correspondence of Eleuthère Irénée du Pont, his father Pierre Samuel du Pont, and his wife, Mme. E. I. du Pont. This correspondence was translated and presented in *The Life of Eleuthère Irénée du Pont* by Mr. B. G. du Pont. I am indebted to Mr. William S. Dutton of the Du Pont Company for the use of this material. I am also indebted to Mrs. B. G. du Pont and Mr. Pierre S. du Pont for reading the original manuscript and offering numerous helpful suggestions.

I am deeply indebted to Professor Ralph Oesper for the use of his excellent unpublished translation of Grimaux and his numerous notes on the life and work of Lavoisier. I have used his notes to augment my own and his translation to check on the accuracy of my final manuscript. I am equally indebted to Dr. Raymond O. Rockwood for editorial assistance in the presentation of the historical background; to Dr. Charles A. Choquette for assistance in translation; to Miss Eva Armstrong, Curator of the Edgar Fahs Smith Memorial Collection in the History of Chemistry, both for the loan of material from the collection and for reading and criticizing the manuscript; to Mr. Thomas M. Iiams and the staff of the Colgate University library for their suggestions and assistance in securing material.

My sincere thanks go to friends and colleagues who have read and criticized the manuscript: Clarence B. Felten, Vera C. Himes, Martin Matheson, Vera Cober Rockwell, Leo L. Rockwell, Arthur E. Wood, and the late Roy B. Smith.

To my wife, Florence Felten French, I owe an unpayable debt for her assistance in preparing the manuscript and particularly for her constant encouragement through a difficult task.

S. J. F.

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The Rise of a Family

THE heavy coach swung past the heath of Gandreville and dipped over the brow of the hill. Ahead lay the spangled valley of the tiny Authonne and beyond, the deep coronet of the great forest of Villers-Cotterets. A tiny gem, fixed by the golden rays of the late sun against the gentle curve of the forest, was the village on a summer day in the year 1580.

Fifty miles east of Paris, it was the country home of kings and the sporting ground of princes. In the depths of the forest ran hare, deer, and wild boar to challenge the skill of royal hunters. In fresh furrows bordering the forest nested the pheasant to furnish milder sport. Woe to the unfortunate peasant who dared disturb a nesting pheasant to plant his crops; and death to him who fenced his lands to prevent the trampling of deer or the rooting of boar. Royal huntsmen must have their sport; the royal chase must go on unimpeded, so royal decree forbade all fences.

The horses needed little urging as they jogged across the valley, for they were going home. So, too, was the young postillion, going home to the land of his peasant ancestors, to the open glades and silvery beeches of the sunny forest, to the cool green of summer and the rich smells of freshly turned earth and decaying manure. Beyond the gray château, his gnarled peasant father still tilled the ancestral soil and lived as a peasant should, unaware that there might be higher things in life.

But young Antoine Lavoisier, postillion in the service of his king, had risen above his father's station. He had travelled to Paris, and even beyond; he had been responsible for the safety

of princes over the fifty miles of rough road from Paris to Villers-Cotterets; he knew his king as only a postillion might. Was he not the first Lavoisier to raise his eyes above the lowly earth? Was he not the first of a line which would climb steadily through two centuries to the mountain top of immortal fame?

Down past the village green the horses broke into a clattering trot which carried the swaying coach up the shaded lane of the park to the massive doors of the château. Already ancient, these doors displayed in their delicate lacework the gracefully carved salamanders of Francis I, who seventy-five years before was king of France and builder of the château. There, too, were the later entwined arms of Henry II and Catherine de' Medici together with the delicate trio of crescents of Henry's mistress, Diana of Poitiers.

Charles IX had lived his short life under the dominance of his mother, Catherine de' Medici. His self-indulgent brother, Henry III, last of the House of Valois to be king of France, now sat on the throne, second victim of his mother's love of power. Internal strife and conflicting factions left little time for the royal family to visit the château. The village, once the summer capital of struggling France, had begun its decline. Not long hence, the château would pass to the hands of the House of Orléans to serve in turn as the love nest of Louis-Philippe and the handsome Madame de Montesson and the house of exile for a king's too wilful cousin.

But the village would have two other claims to fame. It would one day become the birthplace of the grandson of a French marquis and a San Dominican Negro woman, Alexandre Dumas. Already it nurtured the humble postillion, unknown contemporary of the founder of the House of Bourbon, Henry IV. The one would sire greatness in science, the other, greatness in rulers. Both would sire tragedy.

While servants hastened from the great hall to open the coach doors for the duke and his fair companion, Antoine Lavoisier steadied his tired horses. There would be a reward forthcoming for his careful, yet speedy, trip from Paris. Antoine knew his scale of tips for such a job and he knew furthermore the exact purchasing power of each amount. Five livres would buy

a wedding ring for the fair Anne, two would pay the curé and one the fiddler. But, to get all eight livres together at one time was a vital problem.

Perhaps the duke divined Antoine's problem, or, more likely, he had had a good night at the king's gaming tables and was pleased with his fair companion. At any rate, he solved all of Antoine's problems with his generous tip.

Anne was willing and waiting, nor was Anne's father at all displeased at the prospect; his daughter would not plough the sodden ground, sheave the heavy grain, or stumble homeward under a burden of faggots. She would be the wife of a postillion, and not an ordinary postillion at that. For was not Antoine a personal servant of the king?

The wedding of Anne and Antoine was celebrated with due Sunday gaiety in the village of Villers-Cotterets. Anne went to live with her husband over the stables in the royal château park. In course of time, as was to be expected, Anne became pregnant, and when her term had run its course, she delivered a lusty son who was also to be known as Antoine.

What could be more natural than a love of horses to a child born and reared in the royal stable house? At the age of ten this lad could flick a fly from the ear of the lead horse with his father's oiled whip. More than that, with a leatherman's awl and a thong of rawhide he could repair a broken trace as skillfully as his father. He knew horses from hoof to quivering nostril. At fifteen he was wheeling heavy coaches to neighboring châteaux at Lafert-Milan and Château Thierry.

At the age of seventeen, he wheeled his first coach over fifty miles to the Paris of King Henry IV. The bigness of the city and the heavy traffic in the rough cobbled streets disturbed him. He fearfully watched pedestrians diving into protecting doorways from under the very wheels of scurrying cabriolets and heavy diligences. In spite of the fascination of great towers, open squares, thronged streets, and the busy mysterious comings and goings of barges on the river front, Antoine was glad to return once more to the peace of the village.

But Antoine junior would not, like his father, remain a postillion for life. There were greater things in store for him. One

of the post roads from Paris to the channel port of Calais was to pass through Villers-Cotterets and the village would become a stop on this important highway. Here weary travellers would refresh themselves and weary horses would be replaced by fresh ones for the onward journey. Who in the village was more fitted for the position of master of the post than Antoine junior? So Antoine left his quarters over the royal stables for newer quarters above the stables of the posthouse in the village. And with him he took the fair young Marguerite Gosset as wife to keep the posthouse tidy, care for the desires of pausing travellers, and bear him children.

Past the doors of the posthouse moved a busy world on wheels. Somber, long-coated English merchants with their three-cornered hats conversed in foreign jargon or asked for food and drink in unintelligible French. Chevaliers, booted, plumed, and ever ready to defend honor with sword, scurried in and out on their way to wars. Bishops and dignitaries of the Church, robed in scarlet silk, paused to replenish their portly stomachs with food and drink. Ladies of the mode, low-bosomed, high-waisted and attended by their satin-breeched escorts, descended gracefully from gilded chaises. Then, too, there was the usual throng of commoners who poured forth from the lumbering diligences to stretch their legs and relieve their bladders. Important, long-coated clerk jostled stolid peasant in leathern jacket and amiable curé in dirty robe.

The village children found the courtyard an entrancing spot. Each day they assembled to watch the post chaises dash in and out with their loads of important dispatches and to gaze open-mouthed at the curious ever-changing throng from the world beyond. To this group Antoine junior soon added, one by one, his brood of five.

Antoine, called "the younger," was the first-born of this brood, having arrived in the cosmopolitan atmosphere of the posthouse in 1606. But this third Antoine, son of the postmaster of Villers-Cotterets, must not be reared in ignorance of letters as his father, son of a mere postillion, had been. He was hustled off at a youthful age to the village curé, there to learn

his letters and acquire culture. And this learning opened up a new world to the family Lavoisier. Postmaster Lavoisier was proud of his literate son; he should become a man with a profession. So Antoine the younger broke a tradition of two generations to leave the horses and become assistant to the sheriff of the district. This important clerical office marked a distinct rise in the social scale. In June of 1630 he married Madelaine Dubois, daughter of a village merchant. Thus, did the family of Lavoisier become established among the bourgeoisie of Villers-Cotterets.

For ten years the marriage remained barren till it seemed that nature, satisfied with her efforts to raise the family above the soil, had given up the task of further improvement. Then, to the surprise and pleasure of both his parents, Nicholas Lavoisier was born in 1641.

Nicholas had two important qualifications to distinguish him in the family succession. He was the only first-born of the family to forego the name of Antoine. He was also the first of the line, and the only one, to enter business and thereby build up a modest endowment for his progeny.

Nicholas's maternal grandfather was a merchant of some little standing in the village, his father a man of learning. It is not strange, therefore, that Nicholas should become a man of some importance in Villers-Cotterets. First, he learned his letters; then he was apprenticed to his grandfather to study the business of selling. Soon he was an operating merchant, building up a reputation for integrity.

Nicholas broke another tradition; he sought a wife beyond the confines of the village. The family was not only strengthening but broadening itself as well. In 1673, Nicholas brought back to the village his bride, the fair Barbe Lagonée, to live in a new, beamed, stone and stucco house facing the village green. It was not the finest house in the village but it was far from the worst; it was not in the choicest location but it was on the best street. Into this home of affluence and some erudition Antoine, a century removed from his horse-riding great-great-grandfather of the same name, was born in 1678.

In the intervening century France had changed. Henry the Great had emancipated the Huguenots while his wise minister, Sully, had untangled snarled finances. Agriculture, industry, and commerce had moved ahead; so had taxes. The warlike nobles were being brought to heel as the king, using the intelligent bourgeoisie to checkmate them, gathered into his hands the powers of an absolute ruler.

Under Henry's successor, weak Louis XIII, France was really ruled by the iron-willed Cardinal Richelieu. The nobles were forbidden to have fortified castles; bourgeoisie intendants, responsible to the crown, were placed over the noble governors of provinces. The centralization of government kept pace with the apparent prosperity of France.

Under Cardinal Mazarin, appointed by Richelieu as his successor, came civil strife, the last stand of the restive nobles, the revolt of parlement. In October 1652, the thirteen-year-old boy king, Louis XIV, stepped before the parlement of Paris and in a "bed of justice" forced the registering of his edicts. No longer was parlement to meddle with the finances of the nation or affairs of public policy. Henceforth the king was to be the state, a ruler by divine right. The grand monarch had arrived, bringing with him years of splendor for France. The great feudal lords were reduced to mere ornaments to adorn the glory of "Louis the Magnificent." Those who could afford to live at Versailles gained the ear of the king, favor, position; those who could not, sank into genteel oblivion.

The clergy constituted the first powerful order or estate, the nobles the second; all others, four-fifths of the population, the third or lowest order. Both clergy and nobles were exempt from taxation; the lowly Third Estate found itself supporting a great military establishment, a court of lavish tastes. The prosperous bourgeoisie could well afford to pay their taxes but the unfortunate peasants found three-fourths of their meager income going to their landlords, the Church and the state. They were but little above the cattle, sleeping on straw-piles, possessing no furniture, no clothing, except what they lived in, little food beyond the immediate meal. Few could sign their names to their own marriage registers.

Between peasant and noble stood the solid bourgeoisie, the rock of France, the hope of the nation. Each year saw this class gaining in strength and importance. From it came judges, nobles of the robe, and lawyers, doctors and scientists, dramatists and poets. At the time, this class was giving birth to the great literary movement in France, a movement fathered by Corneille, Molière and Racine. In it was family life at its best. Yet, socially the wisest of its members was not the equal of the unlettered, impecunious provincial noble unless he were willing to buy an office carrying with it a title. Already this important class-conscious group was beginning to question such artificial distinctions, the unjust distribution of taxes, the pitiable state of the peasant, even the divine right of kings. This was the class into which the Lavoisier family was rising with the advent of Nicholas.

A widespread interest in science had not yet dawned. On his deathbed, Copernicus had taught the world the heretical truth that the earth was but a satellite of the sun and not the center of the universe as Aristotle had ordained. Galileo had confirmed the heretical theory with the newly discovered telescope. Tycho and Kepler had proved that the solar system was an orderly one obeying immutable laws of nature in its complex convolutions. Sir Isaac Newton, groping forward from these discoveries, was about to announce the greatest scientific discovery of the century, the law of universal gravitation, in his famous book, the *Principia.* These amazing discoveries of orderliness in the physical universe were soon to have their reaction on social thinking as John Locke preached his theory of universal human reasonableness.

In other branches of science, progress had been less spectacular. The works of the Greek doctor, Galen, written before 200 B.C., dominated the field of physiology till Andreas Vesalius challenged them in 1543. His challenge rested on experimental facts, facts obtained against the expressed command of the Church by the dissection of corpses in hidden cellars. A century later, William Harvey, using the newly invented microscope, discovered that blood, pumped by the heart, circulates

in the animal body. It would remain for a descendant of the king's postillion to point out the relationship between that circulation and the process of breathing, between breathing and animal heat, between breathing and life.

In medicine the ancient works of Avicenna, Galen and Rhazes were still the vogue in 1500 when uncouth young Theophrastus Bombastus von Hohenheim pompously set himself up as the Paracelsus of medicine. His adopted name meant "greater than Celsus," the famous Roman physician. Throwing the works of Galen and the others in the fire, maintaining that medicine should be an experimental science, and declaring that the body was a chemical machine, Paracelsus directed attention to the relationship between medicine and chemistry, stimulated the production of chemical remedies and incidentally is credited with starting the search for the "elixir of life."

In chemistry the four elements of Aristotle, air, fire, earth and water, were still the only elements recognized. The dominant theme throughout eighteen centuries had been the search for the philosopher's stone. With this magic powder, one element might be transmuted into another, base metals changed into gold. Again, a descendant of the king's postillion would show the fallacy of such transmutation. But the idea would persist in one form or another down through the centuries, until modern science proved that transmutation was actually possible.

Accompanying the search for the philosopher's stone came many an unscrupulous alchemist whose aim was not to make gold but to trick his patron into thinking he could. Such alchemists cast much discredit on science.

Robert Boyle, a contemporary countryman of Newton, was at the moment developing a remarkably sound theory of combustion or burning; he lacked but one bit of evidence to complete his theory. It was evidence he never found, oxygen. Boyle's theory based on experimental evidence went down to defeat against the more fanciful and popular theory of Johann Joachim Becher, a theory coming not from experiment but from Becher's philosophical head. During the process of burn-

ing, argued Becher, a "spirit of fire" escapes into the air. By proper procedure this "spirit of fire" can once more be imprisoned in a substance and the substance once more becomes combustible. Georg Stahl, Becher's student, was already at work molding his master's "spirit of fire" into the formidable and popular phlogiston theory. It would rule the world for a century till it, too, ran afoul of the clear brain and manipulative skill of the last descendant of the king's postillion.

Such was the state of scientific knowledge in the age of the Grand Monarch, Louis XIV, a century before the fall of the Ancien Régime. The king was the state; the state was rotting beneath its gay trappings and exposing the crude understructure to view.

Of all this Nicholas Lavoisier was scarcely aware. His life and those of his ancestors had run their calm course in the shadow of the great forest. He had become a solid member of the French bourgeoisie, industrious and steadfast, loving family above all and proving to the world that not all France was sinking to decay.

Antoine was the first-born of Nicholas. As behooved the son of a prosperous merchant, he played on the village green, found companions among the sons and daughters of the town's leading citizens and was thoroughly schooled in letters. But even this was not enough for the son of Nicholas. He must needs be educated to a profession of quality. Should it be law, medicine or the clergy? Medicine was scarcely a profession and the monastic life of a cleric made little appeal to the active young Antoine. Law it was. So, the young man was sent off to law school, thereby setting a new tradition in the family. The village could no longer provide adequate educational facilities for its rising family. On his return from law school, Antoine was given the highest award the village could bestow upon him, the office of procurer of the district of Villers-Cotterets. Antoine was indeed a man of affairs and a leading citizen of the village. He must even consort, in line of his duty, with royal blood, for he soon became superintendent of the

great forest and, as such, agent of the House of Orléans, new owner of the château and all its lands.

Antoine must find himself a wife of quality, a wife who could entertain the élite of the village. Like his father, Antoine sought a wife elsewhere. In the neighboring village of Pierrefonds lived the affluent Jacques Waroquier, able procurer of the district and father of three fine sons and two beautiful daughters.

Antoine's duties brought him into frequent contact with his fellow procurer at Pierrefonds and it was not long before he discovered the dark beauty and calm graciousness of Jeanne, elder of the daughters. Jeanne would be the ideal wife to grace his fine stone house, to add prestige to the family of Lavoisier. Jacques Waroquier could see no objections to the match but being an enlightened man he must first ascertain his daughter's feelings toward the young procurer. He had little need for worry. Jeanne had already made her choice.

With due family celebrations the marriage contract was signed and when the bare, somber forest lay against a white underground of snow in January 1705, Jeanne Waroquier became Madame Lavoisier and moved to the now aging stone and stucco house in Villers-Cotterets. It was the sturdy house that Nicholas had built.

The years passed. Jeanne was a perfect wife and an ideal hostess but again it seemed as though nature had decided to end the ascent of the Lavoisiers. Even so, it was not a mean ascent, from peasant to procurer. But nature had two generations yet to account for. So, after a decade of waiting, Jean Antoine was born in the old stone house to grow and play on the village green, attend the village school and reach young manhood, the only child of adoring parents. And he was the last, but one, of his line.

Tradition on both sides of the family demanded a training in the profession of law for this only son. More than that, it demanded training in the best law school in the country. Jean Antoine must be educated in Paris. At the age of sixteen, he took coach for Paris and broke another family tradition, for

he remained in Paris. The village was no longer large enough for the talents of the Lavoisiers.

A record little short of brilliant in law school was followed by a post in the parlement of Paris, the court of law which stood its ground even before the fury of kings, the group of lawyers which alone might nullify a royal edict by refusal to register it.

First, as assistant to his maternal uncle, Jacques Waroquier, procurer of parlement, and later as his uncle's successor, Jean Lavoisier began to carve a niche in the select professional circles of Paris and to build up a fortune which would lead one day to tragic consequences.

The bachelor home of Jacques Waroquier in Paris stood in the cul-de-sac Pecquet, a short blind street within easy walking distance of the Palais de Justice. It was a modest mansion but more than adequate for its lone possessor. To this home young Jean Lavoisier came, on his arrival in Paris. And here he remained.

Jean Antoine was twenty-six when his uncle died in 1741. His income, that of an assistant procurer, was scarcely adequate to maintain a home of the quality called for by both position and ambition. But the will of Jacques Waroquier fortunately remedied that. To Jean was left the little mansion in the cul-de-sac Pecquet together with a modest fortune of some forty thousand livres. Not only that, but Jean was appointed to his uncle's position as procurer of parlement.

Even before acquiring his inheritance Jean had found the girl of his choice in frail Emilie Punctis, daughter of his influential colleague, Sieur Clément Punctis. Like his own family, that of Emilie Punctis had risen from humble origins. She was, on the maternal side, the great-granddaughter of a simple Parisian butcher; on the paternal side was a background of the profession of law, having its roots in the soil of a peasant ancestor. Clément Punctis was not only a well-known advocate of Paris but he was also secretary to the important vice-admiral of France. His was a position of honor and influence; a penniless young man, even though his future might be promising,

did not approach the important Clément Punctis to ask his daughter's hand in marriage.

Emilie Punctis could have married wealthy men, men of title, in fact, for her family was on intimate terms with members of the aristocracy and the family wealth assured a sizable dowry. Furthermore, she was attractive by all the standards of Parisian beauty. Madame Frère Punctis would, no doubt, have preferred a family with finer Parisian connections, but Sieur Clément Punctis admired the refreshing outlook and clean-cut ideals of his young colleague. He would offer no objections to the marriage. He would, in fact, provide a dowry of some seventeen thousand livres to match the modest Lavoisier fortune. Jean Lavoisier was a lucky man; he already had an excellent position, modest wealth and a promising future, and now he might add a charming wife and, incidentally of course, a sizable dowry. Emilie Punctis was equally lucky; she would marry a promising young man reared in fine traditions of family affection and clean living.

On June 5, 1742, the marriage contract was signed with due ceremony in the fine Punctis mansion on the Rue du Four-St. Eustache. From Villers-Cotterets and Pierrefonds came Lavoisiers and Waroquiers; from Paris, the families Frère and Punctis. There was even a sprinkling of aristocracy present for this important occasion.

The Lavoisier family was established in Paris, in the well-to-do middle class. An annual income close to ten thousand livres assured servants and carriage.

A century and a half had passed since the young postillion first rode the king's horses. Slowly but always steadily the family had moved upward to find its place among the prosperously intelligent citizenry of Paris.

The Grand Monarch, Louis XIV, had been dead now for a quarter of a century and the destinies of France were in the feeble hands of his great grandson, Louis XV, he who for a few short years was the "well beloved" before he became the "well detested," the last, but one, of the Ancien Régime.

Though France was prospering, economic stagnation was setting in. The condition of the peasant was improved: He owned more land. But there were still distress, famine, taxes, feudal dues, and rising prices to render his lot a pitiable one.

The great middle class, conscious of its importance and power, conscious, too, of the snubs it received from idle nobles, was becoming more than articulate—it was becoming downright critical of the Ancien Régime. The age of the philosophes, the reformers, and propagandists of France, was at hand. These philosophes, led by Voltaire, Montesquieu, Diderot, D'Alembert and Rousseau, gathered in the salons of Paris to criticize Church and state. They were writing pamphlets, verse and satire. Malesherbes as *directeur de la librairie* was winking at these publications and allowing them to pass uncensored. Diderot and D'Alembert were soon to start work on the famous French *Encyclopedia* which would arouse the ire of Church and crown. Quesnay and Turgot, borrowing some of their ideas from Locke, were founding the French school of physiocrats to bring economic freedom to the nation. Theirs was the doctrine of laissez-faire, non-interference in the natural flow of trade and industry, the doctrine of natural social laws governing the conduct of men as natural physical laws governed the conduct of the universe. Thus were the bases of reform and revolt being laid in France.

Intelligently following the leadership of these great middle-class movements marched the descendants of the king's postillion, the family Lavoisier.

The Youth of a Scientist

CURIOUS eyes of Paris took little note of the small group which entered the ancient parish church of St. Merrys' on the warm afternoon of August 26, 1743. It was merely another christening. A babe born that selfsame morning neither to the purple nor the red was to receive a name.

To the little group of kinsfolk, it was a most important event. Madame Frère Punctis was present as godmother to this, her first grandchild. Laurent Waroquier, director of the Collège Beauvais and great-uncle to the child, served as godfather. Jean Lavoisier was, of course, present to give his first-born son a name, and before God and the world the tiny wrinkled forehead was sprinkled with the sign of the cross while the priest intoned the notable words, "I baptise thee Antoine Laurent." Antoine Laurent Lavoisier, last descendant of the king's postillion, had started his eventful career.

There was little excitement in the early childhood of Antoine, passed in the shade of the great stone-walled monastery of the Brothers of Mercy. When he was able to walk and play there were open fields to romp in and the courtyard of the monastery to explore.

When Antoine was two years old he was joined by his tiny sister, Emilie. The family circle was complete. Soon there were joyous excursions to the village beside the curving forest. Throughout his life Antoine would never forget the peace and quiet which the great forest brought to him. He would return again and again to find solace from an active life at the foot of the silent forest where his ancestors lay.

Then there were frequent trips to his grandfather Punctis's great house on the Rue du Four-St. Eustache. There, too, he felt the glowing warmth of an affectionate family circle. He also saw some of the great men of the city who came to call on his important grandparents.

Gay excursions into the very heart of the great city with his father took them past St. Merrys', and the tall tower of the ancient Church of St. Jacques down to the river front. There, strange barges weaved their leisurely way past the gray towers of Notre Dame and the misty turrets of the Conciergerie, past the Palais de Justice where robed and bewigged lawyers, like his father, came and went. They walked across the great bridge where Henry IV still rode his bronze steed and gazed hopefully toward the *cité.*

Sometimes they returned past the Place de Grève and through the narrow alleys of the slums of Paris. Here Antoine held tightly to his father's cloak, fearful of the creatures he saw. Children mocked at him while elders looked furtively through sunken eyes. One day these children would stand in judgment of him and his kind. But even then he felt a childish pity for these unfortunates of the dirty alleys. With all of its filth and wretchedness, with all of its beauty and splendor, he early learned to love Paris with an ardor which even personal danger could not dissipate. It would be his life, this city of sharp contrasts.

Then tragedy laid its heavy hand on the little family circle. Emilie Lavoisier was a courageous mother, but frail. Two children had sapped her strength till no reserve was left; her service to posterity was done. Gently, as she had lived, she went to join her forefathers. Her children she entrusted to the loving care of her younger sister, Constance; her beloved Jean she left disconsolate. A second tragedy had come to the house of Punctis, for Sieur Clément Punctis died in the same year as his daughter.

Thus it was that two motherless children and a mourning father left forever the happy little mansion in the cul-de-sac Pecquet to take up their abode in the Punctis mansion.

Antoine's childish mind could not grasp the enormity of the tragedy. He knew only that his mother had gone to join his grandfather, and would not return. His happiness, however, soon returned as his mother's familiar face merged into that of her sweet younger sister, his Aunt Constance. Henceforth, she would be his mother, the only mother he would well remember. And Constance Punctis would find an honorable place in history because of her unselfish devotion to the motherless children of her sister. Jean Lavoisier, young and prosperous, still a suitable match for any girl, remained unmarried throughout the rest of his life. Faithfully he served his children till his relationship to his son became like that of elder brother to younger.

The salon of Madame Frère Punctis was not an important one as salons went in Paris, but it was an intimate one. The frivolities of Paris were of little concern to the groups of men and women who were welcomed there, but the vices of Louis, the "well beloved," and the ill fortunes of a war soon to cost France her American empire, the sad condition of the arsenals and the treasury, the latest *vingtième,* a tax imposed to replenish an exhausted treasury so that Madame de Pompadour and her favorites might continue their lavish living: these were subjects which alarmed all serious thinking Parisians.

While ladies (in waiting) consumed their two thousand livres' worth of nourishment annually, peasants hid their bread and wine in the cellar and starved to avoid taxes; barefoot, ragged men and women shivered through the cold streets of Paris during the terrible winter of 1750, while straying children, orphaned or not, were picked up and packed off to faraway Mississippi. And for this, there were eight days of rioting in Paris. The "well beloved" dared not show his face in Paris, and the very name of Pompadour was sufficient to start the mobs on a new orgy. In the salons of Madame Geoffrin, Madame Tencin and Madame du Deffand, the latest love affair, the clever opera or the newest satire of Voltaire might furnish the excuse for witty talk about serious matters; in the

salon of Madame Punctis there was less of wit but no less of serious matters.

Among the most frequent and most welcomed of Madame Punctis's guests was one Jean Ettiène Guettard, and when he was present the conversation invariably turned to the Jesuit order. Raised by Jesuit fathers, Jean Guettard was passionate in the defense of this unpopular order. The parlement of Paris had condemned them and the middle classes hated them. Still Guettard defended them not only vigorously but violently.

A member of the famous Academy of Sciencce, curator of the great museum of natural history established by the Duc d'Orléans in the Palais Royal, and a geologist of note, Guettard was highly regarded for his scientific achievements. But he was scarcely acceptable to a polite society, where his brutal frankness produced personal enemies in rapid succession. To a new colleague in the Academy for whom he had just voted and who tried to thank him for the vote, he replied in his crustiest tone, "You owe me nothing. If I hadn't thought you worthy, you wouldn't have gotten it—for I don't like you." To a lady who had invited him to a party he sent a curt refusal, saying that he was a Hottentot in society. Toward men in power he was a harsh critic, toward subordinates a kindly friend.

Between this crude bachelor and the immature Antoine, a devoted attachment soon sprang up, an attachment which was to last through the life of the fiery geologist and ease his destitute last year—from the generous purse of his young friend. Through the eyes of this wise and experienced counsellor, Antoine began to see a more beautiful nature. Soon the two were making excursions to the environs of Paris to study rock and mineral formations, collect specimens, and examine waters. It was on one of these trips that the young lad met the great Swedish naturalist, Linnaeus. To crabbed geologist Guettard the world owes a debt for introducing the youthful Lavoisier to the fascinating problems of science.

These immature leanings toward science were not discouraged by Father Jean but there was a formal education to

be obtained, a family tradition to be upheld. So Antoine went each day past the gray-walled Louvre and across the Pont des Arts to the portals of the semicircular Collège Mazarin to study the classical curriculum of the day: Latin, French, and literature.

Voltaire and Rousseau had already set the pace in literature. The Encyclopedists, under the alert leadership of Diderot and young D'Alembert, were startling Paris into a questioning mood and arousing the ire of a great Church.

The order of the day was to write—write anything—poetry, drama, essays, satires. So young Lavoisier wrote, as did all other aspiring young men. First he chose the drama as his medium of expression. Next he turned to essays with better success and won a second prize for his essay on the idealistic topic "Is uprightness as essential as accuracy in research?" Would that this boyish effort had been preserved, for it might throw light on later actions.

Attached to the college was the observatory of the famous Abbé de la Caille, who had spent four years at the Cape of Good Hope attempting to determine the exact length of an earthly meridian for a purpose which to a lay world seemed trivial. At the feet of this master, Antoine was privileged to study the geometry of the ancients and the calculus of Newton and Leibnitz. Here, too, he learned of the great laws of the universe, laws controlling the heavenly bodies in their complex travels as surely as nature governed her creatures. It was a world of order and simplicity, not a world of chaos and confusing complexity, which Lavoisier came to know. Here, too, the boy laid the foundations for the man, acquired the great tool of mathematics and the rule of precision which he would carry with him through life; equipped with these tools he might become the master builder of his craft.

Again tragedy overtook the little family. Just as she was budding into beautiful womanhood, Emilie Lavoisier died. The loss of his cherished sister, his playmate through fifteen years of childish rompings and adolescent yearning, was a severe blow to the young man, a blow which left a touch of

seriousness in the frank open countenance. Father Jean and Aunt Constance now lived but to serve the last descendant of the king's postillion.

The training period was over; it was time for an important decision. Should Antoine follow family traditions and study law or should he follow the dictates of his heart and study science? Father Jean argued that there were no professions in science open to a young man. Science was a plaything of lawyer, doctor, priest, statesman or even king, not a vocation. Antoine might become a professor of medicine in a university or possibly a *pensionnaire académiste* by the age of fifty or sixty with a meager pension paid irregularly by a thoughtless government. He might join a holy order, become an abbé like De la Caille, and devote his free time to science. The alternative was to study law, gain a livelihood in its practice and devote leisure hours to the pursuit of science. It was not difficult to see which course the practical-minded Jean preferred for his son. Nor was Antoine one to disappoint so fine a father. He chose to study law—but with faint heart. He would satisfy the formal traditions of a family, provided he might, at the same time, continue the study of science and mathematics.

It was an ambitious program on which the young man of eighteen embarked. At the Paris Law School his days were filled with lectures on the technicalities of law, the procedures of parlements, and the punishment of criminals. But there were free hours in which he rushed out to the Jardin du Roi to study plants and animals under *académiste* Bernard de Jussieu or to the observatory to learn more abstruse mathematics under De la Caille. Evenings he might spend on mineralogy with Guettard. Then there were mineralogical and botanizing trips into the country on free days. To these activities he added experimental work of his own. Soon the Punctis mansion was equipped with the latest in barometers, thermometers and rain gauges. Constance Punctis and Jean Lavoisier were pressed into service as weather observers. Each day at appointed hours the instruments must be carefully read and the data as carefully recorded in leather-backed notebooks. Not only that, but

the young scientist was soon corresponding with other weather observers even as far away as Turkey. This work, started at such an early period, and carried on throughout the life of Antoine Lavoisier, was cut short by death before the immense amount of accumulated data could be organized into useful and valuable tables.

The dual program of science and law would have been too much for a man of lesser courage and enthusiasm, but Antoine was determined to see it through. Social life was out of the question, and while other young men of his age were swaggering about Paris collecting mistresses and creating scandals, learning to wit and to wag, Antoine was eliminating all this from his program and denying himself even to his friends.

To get on with his work he even feigned ill health. So bad did the situation become that M. de Troncq sent his friend a bowl of gruel with the note, "One year on earth is worth more than a hundred in the memory of men." It was no doubt sound advice, but history knows M. de Troncq for one fact only: he sent Lavoisier a bowl of gruel. History knows Lavoisier because he could, nay would, forego food, drink, and even friends to accomplish his great purpose.

At the age of twenty, Antoine Lavoisier had developed a tenacity of purpose, a devotion to science which was a religion in itself. Without thought of the cost to himself, friends or enemies, he would pursue his chosen objectives. Even ethics and personal integrity would not stand in his way. He would remain true only to his highest ideal, the establishment of scientific truth.

He was not robust but he did have the tireless energy which had characterized his ancestors together with the ambitions which had carried his family name from the soil of peasants to the halls of parlement. Though he had no time for Parisian society, he nevertheless had all of the social graces; Aunt Constance had seen to that. He carried the sensitive aquiline nose, the high brow and deep-set eyes of the Lavoisiers. They were eyes which lighted up quickly when the conversation turned to his beloved science, eyes which showed a sensitive

consideration for friend and family, but a flashing signal of danger for enemies. And he would have enemies, many of them.

There was nothing of coldness or hauteur in the mien of this boy of twenty. He was full of ideals and fired by a laudable ambition to establish himself in a scientific career. He willed to emulate Galileo, Kepler, Newton, Boyle. Could he succeed?

The Young Geologist

THE auditorium of the Jardin du Roi was well filled for the occasion. Aristocrats, titled and wigged, pecked at snuffboxes and passed the time idly conjecturing the meaning of the king's latest quip. Just what did His Majesty mean when he gazed from a solitary window upon the death coach of his late mistress, the Marquise de Pompadour, and uttered the seemingly heartless words, "The Marquise will have bad weather"? Would the party of the dauphin gain the king's ear now, or would there be another mistress to rule France with favors from an empty treasury?

The Academy of Science was well represented in the audience. There were M. de Trudaine, president, and young Trudaine, son of the president, the Duc de Chaulnes, M. de Malesherbes, the Comtes St. Florentin and d'Argenson and many others of lesser note in Parisian society. Science and society met on common ground for this occasion. Doctor and lawyer, teacher and priest, statesman and banker rubbed elbows with foreign philosophers of note and mere impecunious students, all present to hear the last lecture of the season.

In the front rows were the students, notebooks in hand, eager to hang on every word and deed of the great teacher. On the lecture desk stood serried rows of chemical apparatus, pelicans and flasks alternating with stills and retorts. All was in readiness; the assistant, nephew to the professor, had made a final check of needed apparatus.

An expectant hush fell over the assemblage as the famous Rouelle entered, wig and cravat awry. What strange things were to be heard and seen this day? The audience settled back with a slight sigh of pleasant expectation.

Guillaume Rouelle had risen from penniless youth to an enviable position among the natural philosophers of France. Member of the Academy of Science and lecture-demonstrator in chemistry at the Jardin du Roi, he was without doubt the most popular and the most eccentric of Parisian scientists. His lecture demonstrations were the vogue, not only for the brilliant experiments which he performed before the eyes of his audience, but for the fireworks of another kind as well. Upon those whom he thought had appropriated his ideas he was not slow to heap public vengeance; the great Buffon, Macquer, and Malouin came in for their share of berating as did numerous German philosophers. During the course of a lecture, volubly gesturing arms were quite certain to come in contact with apparatus; but no matter, "damned nephew" was immediately called in to replace the broken equipment. Forgetting that an audience sat before him, Rouelle might retire to the rear room to find a piece of needed apparatus, lecturing all the while, and express considerable surprise when asked to repeat the lost discourse on his return. Or perhaps he might reveal one of his secret discoveries requesting his audience to keep the matter to themselves. A few days later when some student repeated to him the selfsame discovery, Rouelle was truly amazed at his scientific acumen. Wig, waistcoat and cravat were a great nuisance during Rouelle's lecture and usually found their way to the floor shortly after he had begun. One day Rouelle startled his audience by exhibiting a mixture which he stirred vigorously. "If I were to stop stirring for a moment," he said "this mixture would blow us all up." And it did. Fortunately, the damage consisted of one destroyed wig, Rouelle's, two windowpanes, one fume hood.

In polite society, Rouelle was equally absent-minded, thinking nothing of rolling down his stocking in the presence of ladies to scratch an itching ankle.

But in spite of eccentricities, Rouelle was a fine scientist and a great teacher. Discarding the alchemy of the mystics and the elements of Aristotle, he had modernized chemistry by boldly presenting and demonstrating the doctrine of Stahl, founder

of the phlogiston theory. He was a firm believer in the phlogiston theory, demonstrating its perfection with many combustions. Even metals could be burned or calcined into ash, the phlogiston, as he thought, leaving the metal in the process; then, by heating the ash (or calx) of the metal with a substance rich in phlogiston, such as charcoal, the phlogiston returned to the metal calx once more and the metal was regenerated. Such was the simple theory which Rouelle demonstrated with precision. It was a theory all-embracing in scope, for it explained all types of burning or combustion. Even men and mice came under its rules, for when they breathed, they gave off phlogiston. It was the best theory of combustion science had yet devised.

Rouelle had little trouble in convincing his students of the truth and beauty of this comprehensive theory. Who could doubt it as he watched Rouelle's dextrous experiments? And who could doubt that a spirit of fire existed when he sat dreamily before a blazing log fire and watched the phlogiston spurt forth in the playing, flickering flames? No one, of course, had tried to catch or weigh this spirit of fire, for it was neither catchable nor weighable. No one *would* try it, till it occurred to a young man, now sitting before the master exponent of phlogiston, that something was profoundly wrong with this theory.

At that time, young Antoine Lavoisier was as ardent a phlogistonist as was his master. Eagerly he listened to every word of Rouelle, fascinated by the clever manipulations and struck by the elegance of the theory. In a notebook, in which the famous Diderot had written up Rouelle's lectures, he carefully followed the speaker and added his own notes. But he was not satisfied with this. He must know more, ask questions. So he bothered the master with queries till the irritated Rouelle ordered him out, then repenting, invited him to work in his private laboratory. This was what Lavoisier wanted. He could learn dexterity of manipulation and read the master's books. He was profoundly happy and completely absorbed in his discovery of the beauty of chemical science. Here again was order, not chaos. Order, perhaps, but far from the order he would one day give to that same science.

Happy days with the eccentric Rouelle were about to end. The degree in law was granted all too soon, and in 1764 Antoine's days of formal schooling were over. He might, if he wished, practise law in the parlement of Paris; there was a place waiting for him, a place which Father Jean would be only too glad to have him fill.

As Antoine debated his future course, Guettard was considering another matter, a matter which would for all time save the young lawyer for science. His secret ambition was to see all France mapped with mineralogical charts showing locations of mines, quarries, minerals, and rock formations. He even had the promise of a grant for his work but he was aging; he needed a young, capable assistant. To whom should he turn but to his young friend, Lavoisier? The compact was quickly made. The salary was nominal, but that to Lavoisier was of little concern; he would learn much of the science of nature in his new association. Soon the two were off travelling, mapping the ground of the Île de France adjacent to Paris, gathering mineral and rock samples, locating quarries, studying stream water and water supplies. There were copious notes to be taken and worked over later in the Punctis study or the quiet of Villers-Cotterets. There were, too, theories on the nature of earth and the origin of fossils to be discussed with Guettard.

For studying water Lavoisier adopted the use of the hydrometer, feeling that by determining the density of the water he would have a measure of its purity. Among the minerals collected was gypsum, used so extensively in preparing cement or plaster for Parisian homes that the name Plaster of Paris had become firmly attached to the product. Lavoisier was intrigued by this substance which, when first heated, then mixed with water, set to a firm, smooth plaster. What was the mechanism of this setting and why was it necessary first to heat the gypsum? He set to work to answer his questions in the laboratory. He weighed his materials before and after heating and setting and noted that the amount of water driven off in heating equalled the amount taken on in setting. Unimportant as it might seem, this procedure of weighing materials

carefully was the one thing which would place him above contemporary scientists in a few years. He had, almost unbeknown to himself, infused into chemistry the one thing needed to replace hazy groping with exact science.

He was ready with his answer to the puzzle of gypsum and Plaster of Paris. In 1765, at the age of twenty-two, Antoine Lavoisier presented his first paper on *The Analysis of Gypsum* to the august Academy of Science. It was the first and least important of a long succession of papers. Nor was it particularly novel. Others before him had analyzed gypsum, but none had weighed their materials as he had. The paper was well received, more for the precision of method than for the results.

This, together with meteorological readings and geological jaunts, was not enough. He must needs enter the essay field once more. The city government, desirous of finding a suitable yet economical method of lighting the dark streets of Paris, was offering, through the Academy, a prize of two thousand livres for the best practical essay on lighting. The prize money was of little concern to Antoine, but the subject was one close to his heart. Many a night he had stumbled through dark and dripping streets as he made his way home from the Mazarin, the Jardin du Roi, or from the Trudaine apartment on the Rue des Vielles-Haudriettes.

Into the problem of lighting a great city Antoine now threw himself with his usual vigor. He studied candle lighting, oil combustibles, wicks and reflectors. There were calculations of costs of installation, and maintenance, types of light standards, and even means of financing.

There were many aspirants striving for the prize, among them Jean Sylvan Bailly. Bailly, the future historian of astronomy, visionary liberal in politics, economist of sorts, member of both the Academy of Science and the ancient Academy of Arts was to become one of Lavoisier's firm friends. He was also to become unfortunate mayor of Paris. Now both these men were young, ambitious scientists seeking to gain a slight foothold on the ladder of scientific fame. Lavoisier's paper, number 36, was judged the best of the theoretical class while

the prize for practical papers was divided between Bailly, Bourgois and Le Roy. For the excellence of his theoretical discussion, Lavoisier was awarded a special gold medal designated by the king.

On the evening of August 20, 1766, Antoine, in carefully dressed wig and new satin waistcoat, appeared at the stately quarters of the Academy in the Louvre to receive from the hands of his good friend, M. de Trudaine de Montigny, president of the Academy, the king's special medal. The following day the *Mercure de Paris* carried the first notice to the world that a new scientist was in the making. "The public," quoted the news item, "has noted with pleasure the flattering honor bestowed upon this young man for which there is no precedent in the Academy of Science." Lavoisier was just twenty-three.

The young man had no time to rejoice over his signal honor; he was busy with the many affairs of science. Once more he was off to La Brie with Guettard and in the meantime was studying a memoir on *Air, Water and Fire* from the Berlin Academy.

In 1766, Madame Frère Punctis died, leaving a considerable estate to be divided between Aunt Constance and Antoine. Though Antoine was still two years short of the legal age of twenty-five, Father Jean decided to free his son financially. Not only was there a sizable estate from his mother's fortune but Father Jean was prepared to add his own contribution of some two hundred thousand livres obtained through the shrewd and careful investment in lands of the small legacy left him by his uncle, Jacques Waroquier. Because of Father Jean's farsightedness, Antoine would one day be termed the "son of a land grabber." At the age of twenty-three, Antoine Lavoisier had a fortune of his own, a fortune of some three hundred thousand livres. To the young scientist, this wealth meant little more than the source of more books on science and better apparatus with which to work.

Guettard was planning an extended geological trip to Alsace for himself and assistant. Aunt Constance was deeply worried at the thought of her beloved nephew enduring the hardships

of the road, the bad food, poor beds, dirty hostels and arduous field work. Most of all she feared the bandits with whom, in her imagination, she peopled the highways. But to young Lavoisier the proposed trip was a great adventure.

The journey was to be made on horseback because of the poor condition of the roads. Barometers, hydrometers and thermometers were carefully packed. Weather observations at home were entrusted to Cousin Augez de Villers and Aunt Constance. The courtyard of the Punctis mansion was a scene of activity and excitement on the morning of June 14, 1767. Aunt Constance solicitously examined the baggage to see that her dear nephew had enough warm clothing, while Joseph, the family servant, who was to guard and protect the scientists, busily packed saddlebags.

Finally, all was in readiness and with heartfelt prayers for safety from Father Jean and Aunt Constance and with last minute advice on letters, posts, weather observations, care of the cats and other intimate affairs of the family, the curious expedition set off, pistols protruding prominently from belts. It would be a brave band of bandits who would attack this formidable trio bound on a mission of science.

Seldom a day passed on the trip that Antoine did not dispatch a letter to either Aunt Constance or Father Jean. Even then, weeks might pass before the letter reached its destination on heavily laden post chaises making less than three miles an hour through the deep mud of the king's highways. And seldom a day passed when Antoine did not receive a letter from one of the two in Paris. There was the new litter of kittens to be discussed, the repairs to the stables, the new furniture, the loneliness of the big mansion, the friends who dropped in, a visit to Villers-Cotterets, a message to Joseph from his good wife, and plenty of advice to "spare yourself and keep in good health."

On his part, Antoine kept Father Jean and Aunt Constance busy doing his many errands and unpacking specimens and books which he sent back by the post. There were grain and half-grain weights for the hydrometer to be purchased from

a certain dealer and forwarded promptly, a new thermometer to replace one broken in transit. Then there were other commissions. To Aunt Constance was entrusted the mission of purchasing a new gray suit with gold braid. After consulting half the tailors in Paris Aunt Constance discovered that green, not gray, was then the vogue. So, Antoine received a green suit. Even more embarrassing was the commission to Father Jean to secure some goldfish from the pools of the Palais Royal through Marrianne, Guettard's housekeeper. The fish were to be brought by hand to Bourbonne-les-Bains, there to be delivered to the good family friend, Mme. de Brioncourt. Pity poor Father Jean as he rode over the rough highways of France, goldfish bowl balanced carefully between his knees.

Every step of the trip was of the greatest interest to the young investigator. Each morning, noon and night he must read the barometer and thermometer and record the results. Each stream, lake and pond must have its water tested with the hydrometer. The soil, relief of the ground, rock formations, location of quarries, water sites, minerals, industrial plants and mines, all came in for the closest scrutiny and demanded careful notes. He watched the peasants toiling away under the corvée system, building highways by enforced labor when they should be tending crops, and he resolved that if it ever came within his power to do so, he would help to end this damnable business.

By July 25 the trio was in Basel and a little later in Strassburg where Antoine met the well-known chemists, Spielmann and Erhmann. Here he permitted himself the one extravagance of the trip; he bought five hundred livres' worth of books and prayed his father to forgive him this gross extravagance.

October 6 was the day set for the expedition to reach Bourbonne-les-Bains on its return journey. On receipt of this advice, Father Jean hastened off to get the goldfish and depart for the meeting point. At Montigny there were no horses for the post chaise. A search through the countryside finally produced two farm animals. But the rain had made the roads a sea of mud and the carriage made less than a league an hour through the

dark night. Not till 6:00 a.m. did the mud- and rain-soaked carriage pull up before the Brioncourt mansion. Carefully, Jean disengaged himself from the bowl of goldfish to advise his friends of his presence. Upon the arrival of the scientists, there followed three hours of steady conversation. But there was still work to be done. Samples must be sent off to Bertin, the baths of Bourbonne must be analyzed, and the journal posted to date.

It was not till the evening of the 19th that Antoine finally reached the Punctis mansion after an absence of more than four months. Late into the night, conversation between aunt and nephew continued. Then there was the last barometric observation to record; and so to bed.

Two days later found Antoine off once more, this time to Villers-Cotterets to join his father, visit his aunts and work up his many notes.

In the middle of November he was once more in Paris ready to proceed with the work of preparing the atlas. Troubles loomed ahead for the two geologists. Minister Bertin had not considered the matter of just how the atlas was to be financed. Lavoisier suggested condensing the proposed two hundred thirty maps to twenty-eight; the work could be done in five years at a total cost of forty thousand livres, almost half of which could be obtained from generous and scientifically-minded individuals including himself. But Guettard's cherished project was destined to failure. Jealousy, lack of funds, and private interests interfered. In rage, Guettard withdrew to the museum at the Palais Royal, not, however, before giving his young collaborator a fine rating in his report to the Academy. It was a rating to which Lavoisier answered, "M. Guettard attributes more to me than I deserve."

Lavoisier was to see most of his work in a later atlas prepared under the direction of one Monnet, Inspector General of Mines. He was to see it not as his work but as that of Monnet. Often the paths of these two would cross in the future as both rose to fame but always there was a barrier between them. Monnet's last attack would come four years after the death

of Lavoisier in a bitter but fruitless attempt to undermine the great theory which Lavoisier had so firmly established before the eyes of the world.

The failure of the geological project closed one door to Lavoisier, but it opened a greater door. Henceforth his great work in science would lie in the field of chemistry. He was to bring forth a new system of science.

The Academy of Science

ON the afternoon of May 18, 1768, the famous old Academy of Science held its regular meeting in its stately Louvre quarters. The hall was filled with nobles and commoners alike, but every man, whether of low or high estate, was dressed in the fashion of the day and marked with the symbol of distinction, the symbol which inevitably went with membership in this notable body.

Among the noble honorary members present were: M. de Lamoignon de Malesherbes, M. Trudaine, Director of the King's Highways, M. Bertin, Secretary of State, Maréchal de Richelieu, Cardinal de Luynes, Paulmi d'Argenson, and the Duc de Praslin.

In the presiding officer's chair was the Comte St. Florentin, minister to the king. At the desks of director and assistant director were the active officers of the Academy, M. Duhamel and the brilliant encyclopedist, D'Alembert. Completing the assemblage were the rank and file of the membership including among them such notable names in science as those of Monnier, Lalande, Le Roy, Macquer, Guettard, De Jussieu, Rouelle, Quesnay, Turgot, Bailly, Condorcet, Buffon, and many more.

In spite of free fellowship between noble and commoner, there was a feudal demarcation in rank once the Academy settled to its business of the day. At a long table forming one side of a hollow square sat the nobles, honorary members; flanking them on both sides were the *pensionnaires,* and opposite, the associates. Behind the associates and seated on hard benches came the lowly assistant members. From rear bench to the armchair of a *pensionnaire* the commoner could hope to advance. But only through the grace of His Royal Highness or

the acquisition of a noble title could he ever hope to occupy the plush-covered armchair of a noble member. Nor could he ever aspire to the chair of the presiding officer. Director, secretary, treasurer he might become, but, no more. In voting, unless he had reached the rank of *pensionnaire,* the commoner remained silent.

Routine business disposed of, the Academy turned to the special business of the day. There was to be an election to membership. Some aspirant was to be awarded the high privilege of a seat on the hard benches among the humble assistant members. It was a privilege for which any truly ambitious savant would willingly give an eye.

Elections to the Academy were infrequent, for only upon the death of one of its sixty-eight members was there a vacancy to be filled. Comprising the list of nominees were the names of Monnet, Sage, Baumé, De Machy, Jars, Valmont de Bomare, and Lavoisier. One by one these names were placed in nomination by friends of the candidates. Achievements of the aspirants were noted with redundant rhetoric and flowery phrases.

The nomination of Antoine Lavoisier came last and his name was placed before the patient members by the renowned astronomer, M. de Lalande. "M. Lavoisier," he said simply in concluding, "is a young man of excellent repute, high intellect and clear mind whose considerable fortune permits him to devote himself wholly to science."

The nomination speeches were over; from the armchairs of the nobles to the benches of the assistants there was a buzz of excitement. On the entire list of candidates not one was unworthy; all would be heard from again and again in science.

It was freely conceded among voting members that the real race would be between Gabriel Jars and Antoine Lavoisier. Jars was mature in years; Lavoisier, young. Jars had done notable mineralogical work in the field of mining; Lavoisier had done little more than act as assistant to Guettard in geology. Jars, who had reached the peak of his scientific work, was little known to Parisians, since his life had been largely

spent in foreign lands and provinces studying mining operations. Lavoisier, already showing great promise of a brilliant career, had lived from birth in Paris, and had come to know many leading scientists personally. Four of his papers had already been presented before the Academy. But there were more subtle considerations.

St. Florentin, honorary president of the Academy, De Fouchy, permanent secretary, and Buffon, fiery naturalist, were supporting Gabriel Jars. It was a powerful and influential triumvirate to combat. But the friends of Lavoisier were present in numbers.

Good old Guettard was there to fight, if necessary, for his young colleague. Eccentric Guillaume Rouelle and botanist Bernard de Jussieu could be counted on to support their former student. Pierre Joseph Macquer, dean among the chemists of the Academy, was using his great influence in behalf of the promising young Parisian. Duhamel du Monceau, current director of the Academy and old friend of Father Jean, had espoused Antoine's cause. There were also the influential family friends, the Trudaines, father and son. This was the nucleus of the group supporting the candidacy of Lavoisier; it was a representative cross-section of the Academy. But could it counteract the tremendous influence of the important triumvirate?

Not till the last voting member was polled was it evident where the majority stood and even then the contest was not decided, for democracy was still unborn in France. Final decisions rested with the king alone. He might, if he wished, reverse the vote of the Academy, nullify it, or order a revote. Furthermore, St. Florentin as minister to the king had great influence at court.

The voting was finally finished. Lavoisier had won by a small margin, but St. Florentin was determined to see his candidate seated in the Academy. He therefore referred the whole matter to His Gracious Majesty, Louis XV. His Majesty, sunken in pleasure, unconcerned with affairs of state and less concerned with the affairs of science, cared little who was

appointed to the vacancy. But there were those in the Academy whom it was not wise to displease. So he solved the problem by appointing two men to the same vacancy. It was a method used occasionally in the past to settle deadlocks, the stipulation being that the place should not be declared vacant till both men had died.

Thus did young Lavoisier gain a right to share a hard bench with Jars facing the seats of the great. A year later Gabriel Jars died and Lavoisier's position was regularized. For twenty-five years he would remain a loyal member, passing rapidly from the hard bench of an assistant to the comfortable armchair of a *pensionnaire.* Nay, more, he would become permanent treasurer, director, and at the last, defender of the Academy.

What honor for a descendant of the king's postillion to have his name inscribed on the same pages with those of Newton, Leibnitz, Hales, Halley, Buffon, Condorcet, Bailly, D'Alembert, Cassini, Turgot, Franklin, Linnaeus, Laplace, Priestley, Cavendish and Black! Could he hope to contribute anything to science which would send his name ringing down through the ages as these names have rung?

Antoine could scarcely wait to carry the good news of his election to his father who lay ill at his new country home in Bourget. It was a plan of work and more work which Antoine was evolving, a vista of science for the sake of science which he was visioning. Back in the Punctis mansion, Aunt Constance shed tears of joy for the honor heaped upon the head of her beloved nephew. There were mingled with them tears of sadness, for her boy, now become a man, was widening his horizon and the mansion saw him less and less. From another nephew, Augez de La Voye, came the cheering words, "I see great joy shining in your eyes at the success of your cherished nephew. It is a great satisfaction to know that he has won at his tender years an honor seldom attained under the age of fifty."

On June 1, 1768, Antoine Lavoisier, aged twenty-five, youngest and newest member of the Academy, was formally admitted to membership. There was a courtly welcome to both Jars and Lavoisier by the illustrious St. Florentin, friendly

greetings from noble members and officers and a hearty welcome from rank and file. Even De Fouchy and the great Buffon, their recent opposition forgotten, gave Lavoisier an unbegrudged welcome. It was a proud day for *pensionnaire* Guettard.

With Jars, Lavoisier took his modest place at the rear of the hall. But his inconspicuous position did not prevent the Academy from calling on him for service. Before he could well take breath he found himself on several important committees. As an expert in the analysis of water he soon became involved in the project of the Paris water supply.

For countless centuries Paris had been nourished on muddy Seine water hawked about the town in dirty bags on the backs of dirty men and animals. When the engineer, De Parcieux, had first proposed diverting the more sanitary waters of the Yvette to Paris, the project had seemed economically impossible, but to the ardent young Lavoisier it seemed the only solution to a vital problem. On De Parcieux's death in 1768 Lavoisier took up the project with vigor and, realizing the need for favorable publicity, he wrote in the *Mercure de France*: "One is alarmed when one realizes that the inhabitants of this great capital are nourished on water carted from the Seine on the backs of men or beasts. The scarcity of water contributes enormously to uncleanliness of person and unhealthful air."

The project for better water was not, however, without its opponents, and the public ridicule heaped upon it by Père Félician stung Lavoisier to a powerful retort. On July 15 he defended his stand before the Academy in a paper of such clarity and precision that he influenced even the city authorities. They not only looked into the scheme but actually proposed its adoption. But, as usual, there was little money in the city coffers for such farsighted purposes. Not till 1786 did Paris actually start work on a plan to furnish an adequate sanitary water supply, and not till many years after the death of Lavoisier was the effort finally consummated.

Another project dear to Lavoisier's heart was that of supplying Paris with a system of pumps for protection against the

numerous conflagrations which had from time immemorial wiped out great edifices as well as whole sections of the city. For this project he took many levels with his barometer throughout the city from the Seine to the highest point of Montmartre.

His real work in science was, however, going forward in the laboratory of the Punctis mansion. Thus far, this work had been somewhat sporadic and was concerned largely with geology. Now, however, he was turning to a new field, a field about which he knew next to nothing. Time after time he would come to a dead end and grope in the dark for a bit of evidence. Slowly he would find it and fit it into the new pattern of science.

Lavoisier was disturbed. His method of determining the purity of water by means of the hydrometer had been criticized. The hydrometer measured the density of water and, according to Lavoisier's formula, the lower the density the purer the water. Impurities were, to the advanced-thinking Lavoisier, merely substances dissolved in the water. But what if, as many still believed, water could be transmuted into earth by the addition of heat? The ancient dictum ordained by Aristotle and eagerly seized upon by later alchemists that one substance could be transmuted into another was still believed by many important men of science. Its truth had supposedly been evidenced in many ways. If transmutation were possible, then Lavoisier's method was not only faulty but wholly wrong.

Had Le Roy not presented an important paper to the Academy in which he claimed that earth was an essential part of water, produced there by the agency of heat, and that the hydrometer was therefore useless in determining the purity of water, Lavoisier would never have undertaken his first notable experiment. That Le Roy was not alone in this stand in the enlightened days of Louis XV was evident from the introduction which De Fouchy gave to the paper: "Those, however," he said, "who have impugned the unalterability of water . . . have not done so without the support of weighty reasons." It was necessary for Lavoisier to justify his method, and he did so with a dispatch and a clarity which settled the question of such transmutation for all time.

For his experiment he needed a balance of the greatest accuracy and he called upon Chemin, craftsman supreme, to prepare him a balance which would swing with the weight of a hair. For the vessel he chose a queer-looking vessel, a "pelican," in which the water might boil up into the pelican's wide neck, condense and flow back down hollow side-arms to the belly once more.

With more than customary care he cleaned and weighed the pelican, added pure water and weighed it once more. The pelican was heated, carefully sealed, and on October 24, 1768, placed over a six-wicked lamp of olive oil. For one hundred days the wicks were trimmed and the oil replenished day and night while the water in the pelican went through its endless cycle, evaporating and condensing. If heat, the popular material "caloric" of the day, seeped through the vessel and joined with water to produce earth, the fact would show up in increased weight. It was a simple experiment but conclusive in nature. And in carefully weighing his materials Lavoisier had gone again beyond most of his predecessors and contemporaries. He was doing the one thing needed to settle an age-old controversy.

Eagerly he watched for the appearance of whitish earth in the crystal-clear water. At first, there was nothing but the bubbling water to record in his notebook. Then, white flakes began to appear and increase in number. Perhaps he was, after all, getting earth from water.

But he had another hypothesis. The weights would tell the story. One hundred days had passed. The pelican was removed from the lamp and cooled. Now there must be no mistake in the weighings. There were none; the pelican with its sealed-up water had undergone no change in weight. One point was proved—fire had not united with the water to form the earthy flakes. Then whence came they? Lavoisier reasoned correctly when he assumed that they came from the glass of the pelican itself, for when he weighed the *empty* vessel it had lost weight. One step remained; he must recover the flakes from the water and match their weight against that lost by the pelican.

Quickly, he evaporated the water and weighed the remaining material. Its weight matched that lost by the pelican with but a slight discrepancy. The problem was solved.

Lavoisier was elated. Not only had he justified his use of the hydrometer but he had shown the fallacy of the theory of transmutation of earth into water. Never again would this outworn theory becloud the vision of science. Strangely enough and quite unknown to Lavoisier, the brilliant young Swede, Carl Wilhelm Scheele, had already solved the same problem in a different manner. But the diffident Scheele's results were not known to the world till 1777.

Twice a year, at Easter and at Martinmas, the Academy held its famous open meetings. It was a great honor to an academician to be chosen to present a paper before this distinguished social gathering including, as it did, famous foreign philosophers, members of the royal court, littérateurs from the Academy of Arts as well as ladies dressed in the billowing fashions of the day. Le Roy had presented his paper on water at an Easter open meeting; Lavoisier sought a similar privilege for his answer. The request was slightly embarrassing to secretary De Fouchy. Here was a paper which solved the problem Le Roy and many others before him had missed. Le Roy's paper was still unpublished in the transactions of the Academy. The appearance of the two published papers would prove highly embarrassing to Le Roy—and to De Fouchy. Though there was no adequate reason for refusing Lavoisier's request, sufficient reasons for delay could be found and not till November 14, 1770, a year and a half after his results were in, did Lavoisier present his important paper at a *rentrée publique* of the Academy.

It was the first appearance of the twenty-seven-year-old scientist before such a meeting; it would be, by no means, his last. But, from first to last, his papers would carry forward the attack on ancient dogmas of science, break down, one after another, the sacred traditions of chemistry, and alienate most of his colleagues. For years he would stand alone in his attack, till, one by one, he gathered around him converts.

A young man was thinking clearly, reasoning correctly and experimenting with a purpose. It would be ever thus; random experimentation was over for Lavoisier. Henceforth, each experiment would be thoughtfully planned and carefully executed to answer a stated question. His would be the task of fitting discoveries into a pattern. As Newton molded the laws of a universe from the discoveries of Galileo, Tycho, and Kepler, so Lavoisier would build the foundations of chemistry from the discoveries of Boyle, Priestley, Black, Cavendish and others.

But, as he gained in scientific confidence something was passing out of his personality. The naïve enthusiasm of youth was giving way to the critical attitude of maturity, to the coldness that often accompanies scientific accuracy.

La Ferme Générale

THROUGHOUT its rising generations the Lavoisier family had paid strict attention to its finances. From the days of Nicholas there had been economic independence with a small reserve for suitable investment. Father Jean's careful yet shrewd investments in lands coupled with a Punctis inheritance had finally brought the family to a position of actual, though modest, wealth.

Now, it was Antoine's turn to take over the economic leadership of the family. Father Jean was ready to retire to his estate at Bourget. Antoine owed his economic independence strictly to a hard-working, careful-thinking line of ancestors. He would have been no Lavoisier had he not inherited the desire to build even higher the family's financial edifice. But first, he must find a suitable field for investment. It must be a field which allowed him time for scientific labors, yet, withal, a field in which he could see the results of his own efforts.

It was M. de la Galaizière, family friend and Intendant of the province of Lorraine, who made the fatal suggestion of the *ferme générale*. Here, indeed, was the ideal investment medium. It had been a successful enterprise since the day, centuries before, when a needy king in desperation had borrowed money from a group of financiers and in return had farmed out to them the privilege of collecting—and keeping—certain tax moneys.

Gradually, the great financial octopus had grown, collecting more and more of the indirect taxes and paying to the royal treasury a fixed and stipulated sum each year. Thus, did royalty wash its hands of the debasing work of money-gathering. The inevitable result was that the royal treasury saw less

and less of the tax receipts and the "farmers of the taxes" more and more.

In 1600, Sully curbed the farmers in the interests of his royal master, Henry IV, recovering some two hundred million livres for the royal treasury. Again in 1660, Colbert, great minister to Louis XIV, reorganized the system, placing most of the work of collecting taxes in the hands of a single organization, thereby fixing responsibility and ensuring greater efficiency. It is perhaps too much to expect that a royal master whose mistress could lose a million livres at the gaming table in one night could be much concerned over the loss of millions to financiers who saved him the nefarious work of collecting taxes from peasants.

Each farmer must invest a million and a half livres in the farm, which sum was paid over to the royal treasury in return for a six year tax-collecting lease. From his lease, the farmer must derive sufficient revenue to renew the account for another six year period and give himself a profit—else he must stand the loss. As a rule, the farmers saw to it that there were no losses. There were, however, occasions when some farmers were faced with not only losses but actual bankruptcy.

It is not difficult to imagine the feeling toward the tax farm of the peasant, the shopkeeper, the artisan and the small landowner. Scandal after scandal had crossed the pages of its history. Farmer after farmer had flaunted his millions in the pinched faces of his tax victims. There were, for instance, the protégés of Mme. de Pompadour, rich farmers who speculated in wheat, spent more than forty million livres and died in poverty; Roussel, who spent seven million livres in a few years; La Poplinière of whom Marmontel said, "Never was a bourgeois more of a Prince"; Beajon, who spent two hundred thousand livres to support a bevy of pretty girls to tell him bedtime stories; and others equally flamboyant.

The internal affairs of the tax farm had long been carefully guarded secrets. But in 1774 a confused clerk handed the wrong piece of paper to a reporter and Paris learned things which made it rock with laughter and roar with fury. It learned

that with the granting of each lease by His Royal Highness went also a noble responsibility. Each farmer should have the privilege, nay, the noble duty, of contributing to the support of the royal household. Each "horse" must have a free but noble rider. Topping the list of royal riders came the king himself with the income from one entire lease. Below him rode the dauphin, the royal princesses and aunts with a mere fifty thousand each. Even the governess of the tiny royal bastard, the Duc de Barry, and the physician to the infant's mother, Mme. du Barry, must have their little shares of ten thousand each with an additional two thousand thrown in for an opera star, favorite of a moment.

The farmers had come from various walks of life. In the seventeenth century, they were regarded contemptuously as ex-lackeys and the sons of lackeys. By the middle of the eighteenth century, however, their social status had greatly improved. Many a farmer's daughter married into an impoverished noble house—accompanied, of course, by a handsome dowry. The financiers were patrons of the salons, accepted in the homes of nobles, and themselves constituted a nobility of finance on a par with the nobility of the gown. Many were men of literary or artistic talent. Helvétius was a philosophe and a writer of no mean merit, Reynière, a member of the academy of painting, Adine, a member of the Académie Française.

So greatly had the tax farm changed in a century that Necker could say in 1770, "The farmers are no longer the financiers of yesteryear," and the *Tableau de Paris* could say, "They pay now for their past reputation." Even the philosophes had little to condemn in the persons of the financiers; no longer were satirical plays written at the expense of wealthy, uncouth farmers. Yet the tax farm remained to the end essentially a selfish and vicious organization, opposing the financial reform of minister Turgot, gaining greater profits as taxes increased, and playing the unpopular rôle of bloodsucker of the people.

It is difficult to understand why Lavoisier chose to enter this nefarious organization. His social status as a farmer would certainly be no higher than that which he would have gained

by entering his father's profession, or becoming a member of parlement. He knew the malodorous history of the tax farm, since in his investigation of it he prepared a paper on its history which is still an interesting and important document.

On the other hand, his associations with the farmers were limited to those with men like Creutze, Delahante, D'Arlincourt, and Borda, men who were known for their financial integrity, who did not possess great wealth and who professed to some interest in the arts and sciences. He was no doubt also influenced by men like Helvétius, Reynière and Adine who could combine the work of the farm with worth-while careers. It is reasonable to conclude that Lavoisier was prompted by no other motive than that which would give him considerable free time to devote to science. Yet, it was the most unfortunate step the young man ever took.

It was a step which would cause even his liberal-minded colleagues of the Academy to raise their eyebrows till Fontaine reminded them that, "The dinners he will give us will have all the more courses." There were even those in the farm who objected to the idea of a scientist as a farmer. There would come a time when the nation could not distinguish between the scientist and the farmer.

Fatal events move swiftly, and often, smoothly. Antoine Lavoisier, even though he wished to, could not purchase a farmer's lease; that would cost him a million and a half; he had less than half a million to invest. Fortunately—and unfortunately—the aging farmer-general Baudon was seeking an assistant to share one-third of the expense and profit and a major portion of the work of his lease. So, with a cash payment of some three hundred thousand livres and notes for the balance signed by Father Jean, Antoine took a third interest in the lease of Baudon and became, in March 1768, an assistant member of the hated *ferme générale*. Fifteen years later he was recommended for appointment to the important administrative committee.

Lavoisier was assigned to the committee on tobacco, directed by one Jacques Paulze, an able administrator, liberal thinker,

moderate reformer, and a generous host. For two years he travelled through Picardy and other northern provinces examining customs lines, customs officers, tobacco plants, and manufactories. But always he was collecting specimens, studying rock formations and analyzing water. At Dieppe he delivered a new instrument to Cassini who was hard at work measuring the length of a meridian; at Havre he conferred with Fourray on hydrography. At Dunkirk were conferences with manufacturers and studies of gravel beds. At Rheims he recorded his observations on a particularly brilliant display of the aurora borealis to send off to Macquer. Again he was preparing a paper on the growing of tobacco for Paulze. Not even the beauties of nature and man escaped his busy notice.

The friendship between young Lavoisier and the able Paulze ripened quickly into a comradeship which would carry on through life. Paulze, trained as a lawyer, advocate of parlement and a secretary to the king, was a thoroughgoing liberal. In 1752 he had married Claudine Thoynet, sister of young Abbé Terray, then a mere clerk of parlement but soon to become the shrewd, powerful minister of finance. To the marriage were born Balthazar, Christian, Joseph and Marie. It was to the thirteen-year-old Marie that Jacques Paulze turned for hostess of his popular salon on the death of Mme. Paulze in 1769. In the tax farm, Paulze was recognized as a most able and influential member. When dissension split the operating committees, it was Paulze who reorganized the work of the farm. Named titulary farmer in 1768, he soon became chairman of the committee on tobacco and later, member of the executive committee. It was Paulze who collected much of the material for Abbé Raynal's famous *Philosophical History of the Two Indies*. Severe losses in the revenues of his lease had cost him most of his fortune in his early years with the tax farm. But, with his keen administrative ability he soon repaired the losses to build up a sizable fortune.

The salon of Jacques Paulze was a popular forum on the liberalism of the day. Here were to be found of an evening such liberal thinkers as the Parisian-born Robert Jacques

Turgot. Intendant of Limoges, Turgot was soon to become the unpopular but efficient comptroller-general "with a whole reformed France in his head" as the liberal reign of young Louis XVI began. He was a thoroughgoing physiocrat holding strongly to the belief that "all virtues as well as all riches come out of the soil; that as few obstructions as possible ought to be placed in the natural flow of trade. . . ."

To this same school of thought also belonged Pierre Samuel du Pont, an ardent admirer of Turgot, a frequenter of the Paulze salon and an ambitious young economist. Five years older than Lavoisier, happily married and the father of Victor and Eleuthère Irénée du Pont, Pierre was soon to become one of Antoine Lavoisier's firmest friends. Of him he would say, "I have never known a man more willing to sacrifice fortune for friendship or the public weal." A common liberalism, mutual admiration and respect cemented this friendship. The close association would lead by sheer coincidence to the founding of the giant chemical industry of Du Pont de Nemours in far-off America. Now, they were young men climbing, each his own ladder, to fame.

Another frequenter of the Paulze salon was M. de Malesherbes, round chubby jurist who could laugh and make the world laugh with him. He was a friend of the Encyclopedists, a skeptic, a scholar, a physiocrat and an ardent admirer of Turgot. He would twice serve his king as minister and remain loyal to the end even when it became dangerous and unpopular to do so. It was this same Malesherbes who, in these early years, frequently stopped at the Lavoisier laboratory to see what queer things were going on in science, or to instruct his young friend in the principles of physiocratic doctrine. He might write in the formal manner of the day "Could M. Lavoisier be so kind as to come to dinner on Thursday since he could not come before? M. de Malesherbes will send a carriage for him."

Then, there were the MM. Trudaine, father and son, wealthy and upright, capable administrators and trusted executives of the government. On the death of the elder Trudaine in 1769,

his son inherited both titles and positions as well as a very extensive estate at Montigny. It was this capable young man, ten years older than Lavoisier, Councillor of State, Director of Highways, Intendant of Finances, honorary academician and ardent tax-reformer who became Lavoisier's fast friend and great admirer. In 1772 he wrote from Montigny to his philosopher friend, "I am working diligently to become your fellow chemist. I now have a laboratory that I have not left since it was finished three days ago." It was also this young man who so startled his king by refusing the salary attached to one of his many offices that the great Louis was moved to reply, "Such favors are requested of me so seldom that I am unwilling to refuse you."

At the elaborate Château of Montigny which had entertained Louis XV, Lavoisier spent many pleasant days in the company of the Trudaines, talking politics and economics, experimenting in the new laboratory, strolling through the spacious grounds, or visiting the peasants at their work. The two men had much in common, yet each could learn much from the other. In economics, Trudaine was the master, Lavoisier the student; in science, the rôles were reversed. In the Paris salon of Trudaine on the Rue des Vielles-Haudriettes, Lavoisier was equally welcome; here again he met men of his own liberal and mental cast.

Another ardent physiocrat who found the political and economic atmosphere of the Paulze salon to his liking was the Marquis de Condorcet. With the cold enthusiasm of a "volcano hid under snow" he pursued his liberal ideals relentlessly. They were ideals which would carry him into the very thick of the Revolution, place him in the highest seat at the disposal of a maddened and frightened France, inspire him to draw up a constitution for a free nation. But they were ideals scarcely liberal enough to suit Robespierre or a bewildered people.

Though the paths of the idealistic marquis and the practical-minded Lavoisier were to carry them over similar ground, each to a point of eminence; though there was much they held

in common both in science and liberal outlook, there never ripened between them a rich or a warm friendship. Instead, there remained always a respect tinged with irritation.

The marquis, just one month younger than Lavoisier, obtained a seat in the Academy of Science in 1769 through his brilliant work in mathematics. Though of noble birth and therefore eligible for appointment to the armchair of an honorary member, young Condorcet preferred the hard bench of an assistant and the privilege of a working membership. He rose rapidly, and, on the death of De Fouchy in 1777, became permanent secretary of the Academy. However, his interest in mathematics soon gave way to his intense political leanings and philosophical pursuits. The secretarial work of the Academy fell more and more to the lot of his assistant and he drew, in later years, some sharp rebukes from Director Lavoisier, for his neglect of official duties. On his part, Condorcet the idealist was not slow to criticize the practical economic principles of his co-workers Lavoisier and Trudaine.

Strangely enough, history has even mixed the countenances of the two academicians, placing the features of the marquis on a statue meant to represent the figure of the scientist.[1] But for all their veiled irritation at one another, the two men worked together for a more liberal France, for the interests of the Academy, and for science. At many a novel experiment performed in Lavoisier's laboratory, Condorcet was an interested witness or even an assistant in the demonstration.

Paulze, Du Pont, Turgot, Malesherbes, Quesnay, Trudaine, Condorcet: these, together with a few others such as the enlightened Duc de la Rochefoucauld, were the men who early turned young Lavoisier's mind toward the economic and political problems of a despotic monarchy. They gave to him a social philosophy which he would carry with him through life, a philosophy which called for relief to the oppressed, efficiency in government, restriction of royal prerogatives, yet withal, a philosophy which was far from that of the rabid reformer or

[1] Oesper, Ralph E., "Priestley, Lavoisier, and Trudaine de Montigny," *Journal of Chemical Education,* vol. 13, p. 409, 1936.

the impractical dreamer. His contributions in this field, fine as they were, however, were so far overshadowed by his work in science that Lavoisier, the practical economist, politician, financier and reformer, is hidden beneath Lavoisier, the master of science.

Marie Paulze

MARIE ANNE PIERRETTE PAULZE, only daughter of Jacques Paulze, was a mere child in years but a mature women in physical and mental attributes. Convent training had added a thoughtful and gracious mien to a frank countenance. Clear, blue eyes looked squarely and eagerly at a world as yet untried; a small mouth and a slightly retroussé nose set off the natural pink of healthy cheeks. Intelligent parents and a happy family life had placed the finishing touches on a sweet disposition and a sane outlook. And now, at the early age of thirteen, convent days were over, brought to an abrupt close by the death of a beloved mother. Marie must return to a saddened Parisian mansion to take up the family and social duties her mother had dropped.

This was no simple matter even for an experienced matron. But the radiant Marie was equal to the task. She soon learned to meet and receive renowned statesmen, economists, financiers and philosophers with all the ease and grace of a Madame Geoffrin. Her wit, charm, and gentleness won for her a warm place in the hearts of guest and servant alike. When the conversation turned to serious and intricate matters of economics, finance or science, Marie was an intelligent listener, an informed participant, and, if necessary, a spirited antagonist. It is not surprising that the guests of M. Paulze found their young hostess altogether captivating.

Antoine Lavoisier, eligible bachelor and frequent guest in the Paulze home, saw at first only the little blue-eyed child of his good friend. Soon, however, he became aware of a fine, clear intellect which shone forth unmistakably through spark-

ling eyes. Passive courtesy to a hostess gave way to active interest in a personality. He forgot the child and saw the woman. He found himself talking to her of his trip to the Vosges, of his many geological explorations, of his theories concerning fossils, his laboratory, and his chemical experiments. He found, too, that his interests were expanding as he watched Marie's deft young fingers draw music from the harp or colors from the palette. More frequently than ever before did he find himself at the Paulze mansion. But the discussions of physiocratic doctrine found him less attentive. In his laboratory, the heavy burdens of science were taking on a new lightness, a new thrill to his touch. But he was experimenting with a divided interest. And when he found his polished instruments reflecting not their scientific data, but instead a pair of shining eyes above a tilted nose, he knew that science must wait. The instruments were left to gather dust.

Antoine Lavoisier, who for twenty-seven years had verily shunned all womankind except his devoted Aunt Constance and his great-aunts at Villers-Cotterets, who had given his undivided attention to scientific labors, and had passed by with ease the love fancies of youth, was for the first time fully aware of a problem in the realm of romance, a problem which no cold scientific logic could resolve into a simple conclusion.

Jacques Paulze was not blind to the attachment which he saw developing between his only daughter and his able young colleague. Nor would he withhold his consent to a union between the houses of Paulze and Lavoisier. Both houses were sturdy; both had sprung from the soil; both were reared to the traditions of refinement and honor. It was an ideal match. But Jacques Paulze was a liberal; he would not command his daughter to wed against her choice for either position or wealth. Was this her choice? Lavoisier had not spoken yet; Marie therefore could not.

Paulze was deeply worried. His famous brother-in-law, the Abbé Terray, had proposed to him a marriage between the youthful Marie and the Comte d'Amerval. He had more than proposed it; he had insisted upon it. The house of D'Amerval

though penniless stood high in the favor of Madame du Barry, influential mistress of Louis XV. A marriage between the affluent plebeian house of Paulze and the poverty-ridden noble house of D'Amerval would go far to strengthen the precarious prestige of the abbé in the eyes of the great mistress. And it would, of course, elevate the descendants of the house of Paulze to the aristocracy, open up doors now closed, and pave the way for attendance at court. These, to the abbé, were powerful arguments.

What did it matter that the Comte d'Amerval was fifty, Marie, fourteen; he would die the sooner and leave his countess free. What did it matter that the count was ugly and dissipated? That was no concern of a prospective bride. What did it matter that the count was penniless? Paulze could remedy that with a handsome dowry. And against such trivial disadvantages could be set the rosy pictures of presentation at court, favors from the great mistress, entrée to the best salons in the Rue St. Honoré and relationship to the distinguished but somewhat notorious Baroness de la Garde. It was indeed an ideal match from the abbé's point of view and one, which, without his influence, would be impossible for the lowly house of Paulze to accomplish. Marie did not share her uncle's enthusiasm. The very thought of marriage to the ugly, dissolute count was repugnant to her convent-bred nature. Secretly, she nursed a far deeper reason for refusing to enter into such a bargain. It was a reason which she scarce dared admit to herself in a day when position and convenience rather than love dictated the choice of spouse.

Jacques Paulze had no wish to force this mismarriage upon his daughter. And it would have taken him but a moment to discard the abbe's proposal had that been the only question involved. But the abbé had done more than merely politely insist on this marriage; he had threatened. In his hands were the financial pursestrings of all France. He could make and break financiers, bankers, or farmers of the taxes. A word from Terray would remove Paulze from his post as chairman of the committee on tobacco or even rob him of his post as farmer. It

mattered not that Paulze was recognized as one of the ablest leaders of the tax farm; it mattered not that he was honest, efficient, and hard working. It mattered only that the abbé's wish should be satisfied and his position strengthened, or, as the abbé would nicely phrase it, that the lowly house of Paulze be elevated to the aristocracy. Unfortunate Paulze must sacrifice either his lovely daughter or his little wealth and his hard-earned position. How could he do either?

Marie was heartbroken when she learned the full details of her uncle's scheme. She could not marry the aged "aggressive ogre." Nor could she see her father broken financially on this wheel of fate. On the one hand was happy life with the man she loved and disaster to her kind father; on the other, a life of fear and loathing with a man she detested and security for her father. How could she choose between such alternatives?

Paulze's ire at the abbé's conduct was steadily rising. What was the loss of his post, his income, his standing, even, that they should be placed before the life and happiness of this girl? He could start again; he had influential friends, ability, and the confidence of others. One thing only mattered, his daughter's happiness. Courageously, yet with great misgiving he wrote to his brother-in-law. "I can see, sir, no advantages in this marriage. The count is fifty years old, my daughter, fourteen. He is penniless and I can guarantee my daughter no more than three thousand livres a year. His character is scarcely suited to that of a young convent-bred girl. Furthermore, my daughter has a decided aversion to him and I will not force her to marry him!"

The abbé knew full well that Paulze was an important man on the tax farm; and he could scarcely expect public approval for removing a capable executive to satisfy his own avarice. Farmer-general Bouret took up the defense and wrote to the abbé, "M. Paulze is necessary to the farm. He has instituted many needed reforms, reduced taxes, and is the only man who can reestablish order. His loss would be a great blow to the farm." After all, the abbé was a diplomat and knew when to move circumspectly. It was better not to demote Paulze at the moment.

Antoine Lavoisier had watched helplessly the attempted barter of the one who had come to mean more to him than science itself. His heart was filled with bitterness and sorrow, yet he could not offer his advice or help in this delicate problem. M. Paulze was his esteemed colleague, his superior officer in the tax farm.

Now, however, there was no longer need for silence; Marie must become betrothed to another in order to end the unwelcome suit of the count. Paulze knew his daughter's heart and his colleague's mind. Further, he need not worry about proper financial arrangements; Antoine Lavoisier was not mercenary. The decision was quickly made; the happy conspirators were about to defeat the abbé at his own game of diplomacy. Tiny, blue-eyed Marie Paulze should wed the tall chestnut-haired scientist as soon as banns could be pronounced and contracts signed. For Marie, sorrow changed to happiness; for Antoine, there was peace.

How would the abbé react to this move; would he storm, threaten, and execute, or would he grumblingly accept the inevitable? He not only accepted the decision but he graciously offered his own chapel, that of the comptroller-general in the Neuve des Petits Champs, for the formal signing of the contract. The struggle was over, bitterness vanished. Antoine and Marie might seek their happiness unharried by further threats. Condorcet could soon call Lavoisier "the dignified nephew of the Abbé Terray."

Trudaine de Montigny was delighted over the prospective union between the houses of his two good friends; he sent his best wishes to both. Madame Caze wrote to her brother-in-law, Jacques Paulze, "I am so glad that my niece has escaped the clutches of the Abbé Terray. What happiness, now that all is settled. She is so well trained, and so sensible that she will bring great happiness to her husband."

The financial settlement was simple. Jacques Paulze insisted that his daughter have a suitable dowry though he was in no position to provide the total necessary cash at once. Twenty thousand livres were to be paid at the signing of the contract

and a balance of sixty thousand in six years. On Lavoisier's part it was not, as some historians would have it, a marriage for money; his bride's dowry in its entirety was but small compared to his own wealth. On Marie's part it was not a marriage for social prestige. She had refused a title to marry a commoner. Both were happy in their choice.

Little time was lost between the betrothal and the formal signing of the contract, for the abbé might change his mind. On December 4, 1771, there gathered at the home of Terray de Rozier, brother of the abbé, a choice company to witness the prenuptial signing of the marriage contract between Marie Anne Paulze and Antoine Laurent Lavoisier. From the Academy came an official delegation consisting of D'Alembert, Cassini, De Flury, and Bernard de Jussieu. From the tax farm came farmers-general Bouret, Douet, Puissant, Delahante and others. There were Prevosts and Lavoisiers from Villers-Cotterets, Waroquiers from Pierrefonds, Frères, Lalaures and the brothers Paulze from Paris. Officers of the realm included M. Bertin, Minister of Police; good friend Trudaine de Montigny, Director of Highways; M. Demars, Chancellor of the Chambre des Comptes. Among the nobility were Mme. la Duchesse de Mortemart, Mme. la Marquise d'Asfeld, and even the dowager Mme. la Comtesse d'Amerval. The reconciled Abbé Terray was present. Last, and, next to the young couple, happiest, came the fathers Paulze and Lavoisier and Aunt Constance. Altogether, it was a company of some two hundred representing a colorful and intellectual cross-section of bourgeoisie and aristocracy of the Ancien Régime which had assembled for the happy occasion.

To Aunt Constance, for there were no mothers, went the happy privilege of first signing the contract register beneath the names of Marie Anne and Antoine Laurent. One by one the two hundred guests signed the register and wished the happy young couple well. From Father Jean came the gift of a small mansion in the Rue Neuve-des-Bons-Enfants.

Following close after the signing came the simple wedding ceremony. In the presence of the immediate families and at-

tended only by farmer-general Jacques Delahante, Chief Officer of the Marine of Provence, Hurzon Chevalier, both of whom were distantly related to Antoine, and by the Abbé Terray and Terray de Rozier, uncles of the bride, the quietly impressive ceremony was performed on December 16, 1771 in the abbé's private chapel.

Antoine and Marie went to live in the little gift mansion in the Rue Neuve-des-Bons-Enfants. Then there followed joyous trips to Villers-Cotterets when the buds were bursting and the earth was bringing forth new life. At Bourget they visited Father Jean; at Montigny, the Trudaines.

And now, it was Antoine Lavoisier, equerry to the king, instead of mere M. Lavoisier, for Father Jean, not yet content with his giving, had secured a patent of nobility for his only son. He was now to be a secretary to the king—but only one of some four thousand. The house of Lavoisier had passed from the top rank of the bourgeoisie to the bottom rank of the nobility. The purchase of a title was a common practice at the time. It served to replenish an empty treasury. To Antoine, this change meant little or nothing. He was loath to use his new title and remained M. Lavoisier till he became, as behooved one in time of revolution, Citizen Lavoisier.

Though Marie reached just to Antoine's shoulder and was but half his age at the time of marriage, she was a fair match for him in mental stature. If great difference in age is a deterrent to happiness in marriage, neither of these two ever became aware of it. Quick, efficient and intelligent, Marie was the ideal wife of a great man, guarding his time and talents jealously, keeping laboratory notes, preparing careful and accurate drawings for papers, sketching laboratory apparatus and even translating articles from English for a busy husband. In addition, she was the ideal gracious hostess for a salon which would soon entertain the great and near great in science.

For twenty-three all too short years these two would live together in harmony. The breath of scandal, even in a day when it blew hardest, would never touch their lives. But in

the end, to this small woman would come such pain, such mental torture as is the lot of few women to bear.

There were twenty-three years in which to live a full life and do far more than a full life's work; twenty-three years in which to change the very foundations of chemistry before political revolution in all its madness would sweep over France.

The Genesis of an Idea

PASSERS-BY stopped to wipe a perspiring brow, then stare in frank amazement at the queer monster resting under the hot August sun in the Jardin de l'Enfante. Could it be a new horror of warfare destined to hurl men to destruction or was it an instrument designed by the cunning of science to burn the hearts out of assassins? With its great four-foot beam-supported "eye" turned squarely on a scorching sun, with its massive wooden wheels supporting a huge working platform surmounted with cogs, cranks and levers, the queer contraption might well startle the casual observer.

It was, however, nothing more alarming than the great Tchirnhausen lens, an innocent, though lugubrious, instrument of science designed to focus the sun's warm rays into an intense beam of heat.

Adjusting the lens, working cranks and tugging at levers to keep the awkward eye facing toward an ever moving sun were four unwigged, coatless and ardent academicians. There were the aging Macquer, dean among chemists, young Cadet, Brisson and Lavoisier. Queer business was this. Surely none but scientists—or madmen—would do it. The hot rays of the sun were being carefully focussed on a small clay capsule containing nothing else than well-packed diamonds! Four great philosophers were trying to find out whether the sun could demolish the diamonds. What of it? What if it did—or didn't—who cared? For one, Lavoisier cared. He had a theory which needed an answer and this was the only way it could be answered. He wanted to know of what the diamond was made.

For countless centuries diamonds had supposedly possessed mystic powers of good and evil. They had protected their owners from plague and pestilence, warned their wearers of poisons by flashing dark, or acted as potent poisons to the enemy. They ensured victory, banished ghosts, dispelled devils, brought riches, friends, and youth.

Antoine Lavoisier was no believer in the magic power of gems; he was interested in the diamond merely for its scientific challenge. Why was it that diamonds evaporated when heated strongly, while rubies did not? But the question which concerned him most was whether or not air had anything to do with the evaporation of the diamond. Aging Rouelle, his son-in-law D'Arcet, together with Macquer and Roux had recently heated diamonds. Their conclusion was that the diamond underwent a process of evaporation. But what would happen to the diamond, argued Lavoisier, if all air were excluded during the heating? Would the diamond still evaporate? He believed not. Air was necessary to the process. To test the theory he must have diamonds.

He put the problem to Maillard, the jeweler. Maillard, too, was curious to know the answer. He would even furnish the gems. Lavoisier insisted, of course, on his usual precaution; the gems must be carefully weighed before heating. Packed firmly in chalk, charcoal and clay, imbedded in a clay crucible and accurately weighed, the diamonds were ready for the test.

As the great lens swung its leisurely eye after the sun, the scientists watched with expectant interest the course of their experiment. But they were doomed to failure. Out of a clear morning sky swung the haze to veil Paris in its folds. The sun's rays were powerless to pierce the mist, and the lens stood helpless while the clay capsule slowly cooled. The vagaries of sun and lens had defeated science. But the experimenters would not admit defeat. Carefully, the precious capsule was removed to Cadet's laboratory and placed in his fine new, powerful furnace. In four hours the crucible was distorted to a vitreous mass by the heat.

Now, the diamonds, if any remained, must be carefully removed. Would there be any diamonds within? If not, it would be Lavoisier's first defeat. The vitrified packing was carefully chipped away. Then appeared the superficially darkened surfaces of the gems. Quickly Lavoisier weighed them. They had lost no weight. He was right in his hypothesis; diamonds disappeared when heated only if air was present. In some unknown way, air was responsible for the evaporation of diamonds. Perhaps the diamonds, sealed from air, could not give off their phlogiston. At any rate, it was to Lavoisier an important finding. And it was—unknown to him—his first feeble step in solving a much greater problem. Though he was convinced of the correctness of his conclusions, he realized that this one experiment would justify sweeping claims.

And the results of the experiment did not escape challenge. D'Arcet accused Lavoisier and his colleagues of scientific cheating, the most heinous crime of science. The furnace was not hot enough; the time allowed was too little. Properly carried out the experiment would have had a different conclusion; the diamonds would have evaporated. Old Rouelle was a sick man, broken to a state of paralysis by the very science he loved. Poisonous gases had laid him low. Yet he joined his son-in-law in the attack on his former brilliant student.

These attacks hurt the sensitive Lavoisier. He could not bring himself to answer Rouelle. He said simply, "I admit that it is hard for one who honors Rouelle as I do for his great researches, and for one who was his disciple, to see himself attacked by bitter criticism intended for me alone. I flatter myself that the remarks from the pen of D'Arcet are the results of first heat, and I know Rouelle well enough to know that his bitterness is not from the heart. I protest that I have proved my contention, but whether or no it shall not prevent my living and working with these great scientists for whom I have only the highest esteem." Rouelle would soon cease his struggles against the ravages of paralysis, end his eccentric but brilliant career leaving to his former student the great task of rebuilding his beloved science.

Lavoisier was by no means through with his experiments on diamonds. He wanted to vindicate himself but he also wanted to know what became of the diamond when it evaporated in air on strong heating. Did it merely evaporate or was it changed into something else? His good friend Trudaine de Montigny promised the Academy a fine new lens even more powerful than that of Baron Tchirnhausen, and without its defects. But the great lens of Trudaine, not finished till 1774, came too late for Lavoisier's use. It remained to gather dust in the Louvre till irreparably damaged just before the Revolution. Lavoisier had moved on to greater fields.

Perhaps the diamond, on heating, formed a gas or, as it was popularly called, an air, which could be collected and investigated. Lavoisier decided to find out. This time, using the old lens once more, he heated the diamonds in *air* but enclosed in a vessel so that any gas formed could be collected and isolated. And this time, the great lens worked perfectly. In twenty minutes the diamonds had disappeared. There was a gas formed. What gas was it?

An orthodox chemist of the day recognized only one gas, the air we breathe. True, this air might become loaded with foreign material, particularly phlogiston, which would cause it to behave differently but it could again be purified to good air once more. There was essentially but one air.

The great Joseph Black of Edinburgh had struck a hard blow at this supposition a quarter of a century earlier when he had discovered his remarkable "fixed air," known today as carbon dioxide. This was the air which was evolved from limestone or chalk on heating; caustic lime was left behind. It was this same fixed air which would once more unite with lime to form limestone or chalk again. Black had gone further; he had shown that when the fixed air was driven forth from limestone there was a loss in weight, and when this same air was once more fixed into the remaining lime there was an increase in weight. Such things were unorthodox in the extreme. They struck a sharp blow at the very basis of the whole phlogiston theory. Yet, Joseph Black remained satisfied that the phlogis-

ton theory was thoroughly sound till the startling facts produced by his young French fellow worker convinced him in his old age to the contrary and even explained to him the composition of his own fixed air.

It was this same fixed air which the stuttering liberal cleric and peerless experimenter, Joseph Priestley, had recently found above the mash in brewery vats. It was this same gas which was formed when oils, candles or charcoal were burned. It promptly extinguished flames.

Surprisingly enough, the gas which Lavoisier and his colleagues got from the diamond was this *same fixed air.* Was the diamond, then, a substance like charcoal which burned to give off its phlogiston and form fixed air? Lavoisier decided, with some hesitation to be sure, that it was. "We should never have expected," he said, "to find any relationship between charcoal and diamond and it would be unreasonable to push the analogy too far; it exists because both substances seem to be properly ranged in the class of combustible bodies." And he was right. It was a startling conclusion. Who, on superficial investigation, could dare to liken the hard, brilliant diamond to soft dull charcoal? Yet, they behaved alike and gave identical products.

Lavoisier had made of the mystically magic diamond a simple chemical substance.

He was casting out ancient dogma with startling rapidity. He had thrown off the ancient elements of Aristotle in favor of the more precise elements of Boyle. With canny vision he recognized elements in substances which others had discovered but could not classify. With equal astuteness he realized that some materials classed as elements were in reality complex substances which had thus far resisted all attempts to break them up. He had with one simple experiment put an end to the ancient concept of transmutation. Now, he had put the diamond in its proper category as a simple chemical element. He was rapidly becoming a ruthless critic of traditional science. He was developing enemies among the cultists, the mystics, and even among the scientists themselves. He was becoming hardened

to criticism and with it he was hardening himself. Was he assuming a degree of arrogance toward other scientists who had not his clear vision?

The world will never know just how clearly or how early Antoine Lavoisier visualized his sublime revolution in chemistry. From the day of his birth, the background was being filled in, the paths were leading aright. But other backgrounds, other paths for other men had led aright, too, and these men passed by or wandered off. Robert Boyle, a century earlier, had almost seen the vision which Lavoisier had yet to see. John Mayow and Robert Hooke had gone even farther. They had vaguely seen the whole truth of fire and air but could not grasp it. Their vision gave way to the simpler answer of phlogiston. Mayow and Hooke, like Boyle, lacked the last bit of important evidence for their case.

The loss of an historically important laboratory notebook belonging to Lavoisier, a confusion of dates of actual experiment and later publication, a confusion added to, both by the pen of Lavoisier and the pens of others, has shrouded in uncertainty the genesis of a great idea. Only one thing is certain, there was a genesis, a vision of a reformation and it came with startling clearness to Antoine Lavoisier and to him alone. His own story in his own hand in his own private laboratory books proves that. The words are there. But to justify himself in later years, to strengthen his disputed claim, to ward off bitter opposition and scientific pressure he sometimes claimed an earlier clarity of vision than was justified by his own work. More than this, he claimed credit for what he did not do. The wonder is not that he was sometimes confused, vacillating, obstinate, greedy, hasty or lacking in clarity, but rather that he could succeed at all against the tremendous odds. Without his careful use of the chemical balance and the almost unconscious use of a great chemical principle he must assuredly have lost.

In September 1772, Antoine Lavoisier bought from the pharmacist, M. Mitouard, an ounce of "good German phosphorus for forty-five louis." Phosphorus, first of the elements to be knowingly prepared and isolated by man was an intriguing substance to all chemists. It is not surprising that Lavoisier

decided to experiment with it. Nor did he expect any startling results. He expected, probably, to amuse his friends with its unusual properties. He placed some of the phosphorus in a closed bottle and was rewarded by the usual white fumes. He placed the bottle near the fire; the phosphorus burned and the fumes increased for a moment then the action stopped. Why did the phosphorus stop burning? Perhaps the air in the bottle had become saturated with phlogiston and could take no more from the phosphorus. That, at least, would be the answer of an orthodox phlogistonist. Lavoisier was fresh from his work on diamonds. Phosphorus behaved much like the diamond, but fixed air was not produced. Just why Lavoisier chose to question the orthodox explanation of the burning of phosphorus has never been told. He never told it; perhaps he never knew why. Was it a scientific "hunch"? But for some uncanny reason he chose to question it. He wrote in his notebook on September 10, 1772, "I wanted to find out in the same apparatus whether phosphorus absorbs air in burning." Why should Lavoisier raise such a question—it was quite contrary to theory?

Phosphorus, he found, did absorb air when it burned, lots of it. This fact he first explained in terms of phlogiston. The phlogiston, he argued, flew out of the phosphorus; and the thick white fumes united with air. In essence, then, air combined with phosphorus. If this were so, there should be an increase in weight. The balance again. The careful checking of each step in his thinking. Air had weight, phosphorus had weight; if they combined, the product must weigh more than the phosphorus; it must be the sum of the weights of phosphorus and air.

Here again was this brand-new principle in chemistry. Only Black had consistently and successfully used it before him. It was a principle that he would one day enunciate for the world of science to follow ever after, the principle of conservation of mass. "Nothing is created or destroyed in the operations of art, nature or man, it merely changes form." This, the cornerstone of all chemical science, implied in earlier works of Black and Cavendish but never brought into the clear light of day till Lavoisier showed that it could be applied with mathematical

precision to chemical reactions, has remained the most fundamental of chemical principles. Only with his balance could Lavoisier have discovered this great truth. And only through its use could he have produced his revolution in chemistry.

If phosphorus increased in weight and absorbed air when it burned, what about sulfur? He tried sulfur. It, too, appeared to absorb air, increase in weight and form an acid with water. If these substances gained in weight when burned, what about metals which were heated till they were converted into ashes or calces. Was this a loss of phlogiston, or was it absorption of air? The balance would tell. If they lost phlogiston they must lose weight; if, instead, they absorbed air they must gain in weight. If the process were reversed and the calx converted back into metal once more, there should be a loss in weight if air was removed.

Now, he must have time, precious time, to investigate this matter further. If there was to be a revolution he wanted to be the chief revolutionist; yet he wanted to publish his results to the world. If phlogiston was a myth the world should know of it, and from his pen. How could he protect his further investigation? He could send a sealed note to the Academy to be read only when he had further evidence. Quickly he prepared the note. He concluded, "This discovery which I have established by experiments that I regard as decisive, has led me to think that what is observed in the combustion of phosphorus and sulfur may well take place in the case of *all* substances that gain weight by calcination or combustion—This discovery appearing to me one of the most interesting of those that have been made since the time of Stahl, I felt that I ought to secure my right to it by depositing this note in the hands of the secretary of the Academy to remain sealed until the time I shall make my experiments known. Paris, Nov. 1, 1772."

The note was dispatched to De Fouchy. Lavoisier plunged ahead into the unknown, into a new and fascinating problem. The sealed note is eloquent proof of the fact that Lavoisier had come unaided by the work of others to his own remarkable conclusion. But not till 1932 when Meldrum carefully studied the private notebooks of Lavoisier and revealed to the world

the train of thought of the great theorist through his own words, were some critics convinced that Lavoisier came by the genesis of his idea from his own work. Said Meldrum, "The note (of Nov. 1, 1772) bears out his claim. It is a finished composition, thought out, thought through, written with conviction. Facts that are insignificant, each taken by itself, are brought into a relation with one another that proved to have an immense value in chemistry.—Absorption of air accompanied by increase in weight, production of air accompanied by decrease in weight, on these simple principles he proceeded to establish his doctrine on combustion and, more than that, to establish a new system of chemistry."[2]

The next few months found Lavoisier busily engaged in searching the background of his new problem. He was entering a new field, the field of gases or airs, about which he knew next to nothing. Boyle, Mayow, Hooke and Hales had given the early impetus to the study of gases and this phase of experiment had remained largely an English property. Then came Black, Cavendish and Priestley to push still further into the realm of gases. On the Continent such work had been quite largely ignored. Lavoisier must enter a field quite foreign to him, but he entered it without fear.

In his notebook on February 20, 1773[3] he wrote, "Before commencing the long series of experiments that I intend to make on the elastic fluid that is set free from substances, I feel impelled to set down here some considerations in writing, in order to outline for myself the course that I ought to take—I have felt bound to look upon all that has been done before me merely as suggestive. I have proposed to repeat it all with new safeguards, in order to link our knowledge of the air that goes into combination or that which is liberated from substances, with other acquired knowledge, and to form a theory. The results of the other authors whom I have named, considered from this point of view, appeared to me like separate pieces of a great

[2] Meldrum, A. N., *Archeion,* vol. 14, p. 30, 1932.

[3] The actual date in the notebook is February 20, *1772* but historians regard this as a mistake of the type commonly made shortly after the beginning of a new year. The notebook clearly covers work done in the year 1773 and not 1772.

chain; these authors have joined only some links of the chain. But an immense series of experiments remains to be made in order to lead to a continuous whole."

Here was the vision, simply and clearly expressed. It "conveys a great impression of Lavoisier's strength and ardour of mind and of his confidence in himself. It reveals a project that he had formed of doing work that would bring about a revolution in physics and chemistry: he aimed at nothing less. . . . The memorandum has a note of exaltation and even of inspiration. Nothing like it can be found in Hales, Black, Cavendish, Priestley, Scheele. Lavoisier applied his imagination to what he saw of the past and present and he foresaw a revolution in science."[4]

There followed omniverous devourings of the work of predecessors and contemporaries on gases. Priestley's work on gases was given the greatest care, for he was the master experimenter on gases of his day. Beside him Lavoisier was a mere novice. To link all this work together in one volume would be a fine gift to science. Lavoisier decided to publish a book detailing both the history of gases and his own experimental work on the new theory.

He was testing gases with limewater, placing sparrows, mice and rats in the gases to see what happened, seeing whether lighted candles or red-hot charcoal were extinguished by them. He had found something significant. The gas which was evolved when metals were heated with charcoal was none other than Black's fixed air. Why should fixed air come from such a process? Lavoisier was frankly puzzled. Was this process of the reduction of a metal calx similar to the heating of chalk or limestone; was fixed air the key to his whole problem? Perhaps it was fixed air which united with phosphorus, sulfur, and metals when they burned and was released again when the metals were reformed. Yet candles were promptly extinguished in this same fixed air; could it, then, be the gas in which burning also took place? Lavoisier was puzzled and confused. The revolution was not proceeding smoothly. Something was lack-

[4] Meldrum, A. N., *The Eighteenth Century Revolution in Science*, p. 10. Calcutta: Longmans, Green.

ing. It was something which no man had yet discovered, but it was just over the horizon now. Soon its beam would be unmistakable.

Again and again he was working away at the perplexing problem, repeating his work on phosphorus and sulfur, heating them in air and in a vacuum. In a vacuum they did not burn. Boyle had shown that a century earlier, but Lavoisier wanted to be sure.

Though he had by no means accomplished his one-man revolution, Lavoisier decided to release his sealed note and stand by the consequences. On May 5, 1773, the sealed note was opened and read to the Academy. Its contents were received with mixed feelings; some regarded it as a bold attack, some as a foolish enterprise, and some as of little consequence; but none could see in it the vision Lavoisier saw, a revolution in chemistry.

To write a book on a new subject, to gather together all the loose historical ends, to cull carefully the significant facts and on top of all this to include a most significant set of exhaustive experiments is normally a task of years. But Lavoisier could not wait; he was impelled by the urge of a crusader. The book must be finished and off the press before the year was out. And it was. Even an illness of two weeks, delays in the building of "various appliances" because "the workmen have been slack" could not stop the forward surge. In the fall the book went to the publisher. By December it was in the hands of the Academy. On December 7 the committee appointed to review the work duly reported on it. The committee was a friendly one consisting of Trudaine, Macquer, Le Roy and Cadet. It was a foregone conclusion that the book would be praised. And it was. "It is to be noted," stated the report, "that M. Lavoisier has tested all his results by measure, by calculation, and by weight, a rigorous method which is, happily for the advance of chemistry, beginning to become indispensable in the practice of that science." Strange report; the analysis ignored the difficulties besetting the reasoner and emphasized the accurate method. And stranger still, evidence strongly points to M. Lavoisier as the actual author of the favorable criticism on M. Lavoisier's book.

Lavoisier had, indeed, become a power in the Academy if he could write his own criticisms. Had he, too, begun to change his ideals of science? Was he bent on glory rather than science?

Complimentary copies of the book went forward to Black, Priestley, Scheele, De Morveau, Franklin, and others. Strangely enough, the shy Cavendish was not included. Lavoisier had made a mistake in not studying the works of Cavendish more carefully. "But he was captivated by Priestley who was the most brilliant and uncertain chemist of the age"[5] even though he referred to Priestley's work as "a web of experiments almost uninterrupted by reasoning." Soon came translations of the work into English and German.

With all the praise, with all the favorable commendations, the book was a failure from Lavoisier's point of view. "He himself began work with a view to a revolution in science and had ended by concurring with Black: for the rest, one finds him struggling with adversity in the form of his own errors,"[6] writes Meldrum. He had, unfortunately, overlooked the work of some of his own countrymen on gases. Insignificant as this work might have been in Lavoisier's estimation, it should have been included. So he hastily added four chapters to cover the work of Duhamel, Rouelle, Bucquet and Baumé. Failure to give due credit for the work of his predecessors was a major sin which Lavoisier was beginning to commit more and more frequently.

The confusion into which he fell regarding the relationship of fixed air to combustion was his undoing. He could not decide whether fixed air was or was not the important key to all combustion. Black would say: quicklime plus fixed air yields chalk. Should Lavoisier then say: metal plus fixed air yields calx? Or was it some other gas? At least he would not use the phlogistonists' expression: metal *minus* phlogiston yields calx. Nothing was lost when a metal became a calx; something was added. What was it?

This was the key which was still missing. Had Lavoisier tried heating lead calx without charcoal he might have found the hidden key. Priestley would get there first, and, even though

[5] *Ibid.*, p. 33. [6] *Ibid.*, p. 32.

he could not fully understand the significance of what he had found, he would nevertheless reap undying glory for his discovery of the most important element in life.

During the feverish days and hours spent in the search of this new truth, young Marie Lavoisier was working beside her husband. She was his confidante, his foil for ideas, his assistant at the experimental bench, his collaborator. By no means the least attractive parts of this book were the many accurate drawings sketched by the deft hand of Marie and signed "Paulze Lavoisier." She, a better student of English than her husband, spent busy hours ferreting out material from English manuscripts. Nor did she stop with English translations. She wrote her brother, Balthazar, "When are you coming back? My Latin needs you. Come and make me decline and conjugate even though you are bored. You will thus give me pleasure and make me worthy of my husband and your regard." From the great and popular David, she was taking painting and drawing lessons the better to aid in her husband's work.

For Lavoisier, days were filled to overflowing with activity. Affairs of the tax farm must not be neglected either. As a member of the committee on tobacco he recommended reducing the amount of water used in processing tobacco. In 1786, the percentage of water was reduced from six to less than three. Strangely enough this important recommendation would be overlooked or forgotten at a later day.

Then, there was the amusing yet disturbing storm over grating. All France was divided into grating and anti-grating camps. To grate or not to grate tobacco was more than an issue, it was a financial problem for the farm. By law of the tax farm, tobacco must be sold in rolls. If the consumer wished his tobacco grated for his snuffbox, he must do it himself. It was too easy to adulterate grated farm tobacco with contraband tobacco. But retailers were grating their tobacco in spite of farm rules—and adulterating it, too. Delahante was for strict enforcement of the rule prohibiting retailers from grating. Lavoisier and Paulze stood together as favoring grating. The farm, they believed, had no right to dictate in what form tobacco should be sold. The decision, however, favored Delahante. Tobacco must

be sold in rolls. Let the populace grumble if it would. Tobacco had always been sold in rolls and therefore always must be sold in rolls. On such seemingly trivial decisions rested the lives of men.

Side by side went forward the work of the farm and the laboratory. Lavoisier was by no means discouraged by the inconclusive results of his experimentation. He must stand by his hypothesis or face ridicule. But he needed evidence of another kind. Metals should increase in weight when calcined in the presence of air if his theory were correct. He had, as yet, not sufficient evidence for this. He must establish the fact beyond doubt. Lead and tin were the best metals for such work.

The great Irishman, Robert Boyle, had heated metals in sealed glass vessels whereupon they became partially calcined. Was the calcination caused by particles of heat or caloric passing through the vessel from the flame and joining with the metal as Boyle believed; was it the loss of phlogiston from the metal to the air as Stahl believed, or was it the union of the air in the vessel with the metal as Lavoisier believed? A simple test with the all-important balance should tell whether it was caloric which caused the change. If there were no increase in weight of the sealed vessel during heating, then no caloric could have entered, for even caloric must have weight according to Lavoisier's principle of conservation of mass.

A second test with the balance would show whether phlogiston had been given off or air absorbed. The metal could be weighed before and after calcining; a decrease in weight meant loss of phlogiston, an increase, absorption of air.

The experiment was not a pleasant one to perform since the air-tight vessels had a marked tendency to explode when heated. With an iron mask and goggles to protect his eyes, Lavoisier watched the progress of his crucial experiments. The tin was carefully weighed as were the sealed vessels. Gradually the heat was raised till the grayish-white ash appeared and spread over the surface of the metal. Now the vessel must be cooled and weighed. To his great surprise, he found that the vessel had lost weight slightly. On the morrow he weighed it again; this time it had gained weight slightly. These were

puzzling results but, nevertheless, he was convinced that there was no net gain or loss. Lavoisier did not know what every chemist knows today that there is always a film of moisture on cool glass vessels which no amount of cleaning or polishing will remove. But the very fact that he noted these slight weight discrepancies is a tribute to his highly accurate process of weighing. It was evident that caloric was not the cause of calcination.

The next step was to open the flask carefully, remove the calcined metal and weigh it. As he opened the vessel, air rushed in with a hissing sound. Boyle had noted that but could not explain it. Lavoisier had an answer. This air replaced that absorbed by the metal. He was sure now that the tin calx would weigh more than the tin.

He was right; it did.

Though the work was hastily done and the evidence was not all that could be wished for, he nevertheless was well satisfied that his theory of calcination and combustion was correct. It was evident that Boyle had missed the correct answer because the balance was, in his day, merely a convenient mechanism for tradesmen to use in weighing merchandise. It had not yet found a place in science. Black had used it, but Lavoisier was making of it the chemist's fulcrum to a new and greater science.

Lavoisier had made a discovery of the first order in science. Whether he had solved the problem of combustion or not, he had shattered the theory of phlogiston. De Morveau might argue that phlogiston was endowed with the spirit of levity and therefore made those things lighter which it entered and heavier which it left. To Lavoisier and his balance this was just another bit of wishful thinking. Material substances could not have negative weights. Newton had shown that clearly enough in his great law of gravity.

The results of the calcination experiments were ready for publication in the spring of 1774. Lavoisier would like to read them at the Easter open meeting. They were results of the utmost importance and he had the anxiety of a man on the verge of a great discovery who fears that another may anticipate him. His book had already stirred considerable activity in gas ex-

perimentation. Bayen was at work studying mercury and its calx; he was publishing his results in Rozier's new *Journal of Physics*. Lavoisier, too, was publishing articles in this journal. Wrote Bayen, "my experiments have much in common with some of those that M. Lavoisier . . . has just published in an excellent treatise on the existence of an elastic fluid fixed in some substances." If Lavoisier was to carry through his revolution single-handed he must beat his contemporaries to publication.

But there were others ahead; Lavoisier's paper was held over till the Martinmas meeting. Still other disappointments awaited him. He was to be stripped of the glory of this discovery. He was not the first to note an increase in weight when metals were calcined. Even while he was reading his famous memoir in November, Father Beccaria, noted physicist of Turin, was writing him describing his own work on calcination. It was work, incidentally, done more neatly and precisely than Lavoisier had done it and accomplished fifteen years earlier. Lavoisier was crestfallen. "It concerns me," he wrote in the *Journal,* "that the public should be convinced as soon as possible, that I have no mind to appropriate to myself another man's results; and I am convinced that delicacy in literature and science is no less essential than in morals. Although the experiment of Father Beccaria somewhat lessens the novelty of my experiments, I declare to you that his letter has given me great pleasure and that I am delighted to see adopted and confirmed by a celebrated physicist the theory of the increase in weight of metallic calces which I thought I had been the first to develop." Would that Lavoisier himself could have found it convenient to use, at a later date, the advice he here gave concerning delicacy in science.

But Lavoisier had one bit of consolation, Father Beccaria had not seen the great significance of his own work; to him it was merely an isolated experiment. To Lavoisier, it was a link in a chain. He had conducted his experiment to substantiate a profound theory, not to get a casual result.

Then, too, Lavoisier had been preceded in a sense by Priestley who had noted that some air was absorbed when metals were

calcined in closed vessels. But, again, this was merely a random experiment, an accurate but casual observation much like that of Boyle. Had Lavoisier the randomness of Priestley, or Priestley the astuteness of Lavoisier, what a combination science would have seen!

Beccaria had neatly stripped Lavoisier of priority only to be stripped himself. Bayen could not claim credit for the discovery though his work was similar, very similar, to that of Lavoisier. But he was ready to produce a forgotten Frenchman who would antedate them all. In his browsings he had come across a rare little volume written by a long forgotten physician more than a century before. In this book he found experiments illustrating the very point Lavoisier had so proudly presented. It was Jean Rey's book on the calcination of metals. Rey had guessed remarkably close to the truth. He found that metals absorbed air when they were calcined and concluded that the air in some way became thickened and stuck to the metals making the calces denser than the metals. Here were not only results but conclusions as well, almost identical with those of Lavoisier. They lacked only the exact verification of the balance.

Once more Lavoisier was beaten and this time there was less consolation, for Rey had seen almost as much significance in the results as Lavoisier himself saw. Rey's work, however, was done before the birth of the phlogiston theory, hence he, unlike Lavoisier, had no mental barrier to break down. Lavoisier recognized the profoundness of Rey's observations publicly, when he said, at a later date, "Jean Rey, in a work published in 1630, propounds views so profound, so like those that experience has since established—that for long I could not suppress the suspicion that the essays of Jean Rey had been published at a much later date than that shown on the title-page of his book." Did Lavoisier suspect a trick on him? Hardly, for the book was authentically old. Nevertheless, Lavoisier failed to mention the work of Bayen in his revised memoir though he gave due credit to Priestley, Beccaria, and Rey. Did he feel that Bayen's work grew out of his own suggestions and was therefore not original enough to be recognized? History does not reveal the answer. At best, it was an ungracious act.

The work on calcination had cleared up another important point, swept one more cobweb from the mind of the theorist. Fixed air no longer confused him. It was not fixed air which combined with metals when they were calcined; it was not fixed air that played the important rôle in combustion. It was "something in the air" which combined, leaving the remaining air "deprived of its fixable part." Air was a "mixture" or possibly a "compound" only part of which could be fixed in metals. "There exists in the atmosphere," he said, "an elastic fluid of a particular kind which is mixed with the air, and when . . . this fluid . . . is consumed . . . calcination can no longer take place."

He was settling down to a consistent theory and one with all the elements of truth in it. There remained several important steps yet to take. But by far the most important problem was to discover just what was this mysterious elastic fluid in the air. This step he was unable to take, and without it he was helpless. He had uprooted phlogiston to his own satisfaction, but he had nothing more substantial to put in its place.

Strangely enough, even before he presented his revolutionary memoir on Martinmas Day, the answer to his problem, the key to his puzzle was at hand. But he did not know it. Events were moving so rapidly that he had scarce time to ponder one problem before he was plunged into the next. He was groping, not blindly but awkwardly, toward the full light of knowledge. The stage was set, the background sketched in; all paths were converging and the lights were coming up. The man and his opportunity were met. Others might pass it by, he would not; for his mental background was ready and waiting to receive it. Already it was rising from the haze of confusion to stand before him in all its significance, the key element.

Joseph Priestley Makes an Important Discovery

IT WAS Sunday, August 1, 1774. And for England it was a rare, sunny day. In all parts of the land the faithful were putting a last-minute shine on Sunday buckles, donning silken stockings, adjusting hoops in their best satins, gathering family prayerbooks in hand and shepherding cherubic children down the lanes to the Sunday church parade.

For one sinner there would be no church parade, no donning of silks, no listening to droning texts. This sinner was a "heretic" who had long ago revolted against the doctrine of eternal damnation and the self-righteousness of the established church. He would spend the bright day in the calm of his laboratory working with his fine new lens. Minister of the gospel though he was, no moral scruples would deter him from utilizing to the fullest the rare opportunity of a hot, bright sun. Safe at fine Bowood House, summer residence of the great liberal, Lord Shelburne, he might do as he pleased.

So Joseph Priestley donned his leather apron and repaired to his laboratory. Already he was a famous man. His sermons were bad, his speech halting but his rapier thrusts at conservative ministers of the government were disturbing. His writings on Christian dogma were almost more than clerical England could stand. Master of seven languages and one of the most prolific writers of any age, his books on religion were seldom read by any but "heretics."

Violent sympathy for the overtaxed colonies of America brought its rewards. First had come a meeting with that shrewd representative of the Pennsylvania colony, Benjamin Franklin,

and with it came the impulse which was to send Priestley to fame as a scientist and to Pennsylvania for a last resting place. From Franklin came the inspiration to write a book on the *History of Electricity.* Priestley knew nothing of electricity but he was willing to find out. What he couldn't get from books and papers he found out for himself by experiments—clever experiments which won him a coveted place as a Fellow of the Royal Society and brought him the honorary degree of Doctor of Laws from the University of Edinburgh.

Priestley was a firm supporter of Lord Shelburne, Secretary of State in charge of affairs of the American colonies. But Shelburne's attitude was too conciliatory to suit England's strict colonial policy. So in 1768, Lord Shelburne was relieved of his charge. In retirement at Calne in great Bowood House, he was lonesome; he needed a companion and librarian to suit his studious tastes. The liberal Dr. Price recommended Priestley. Thus it was that in 1772 Dr. Priestley moved with his wife and three children to the small house adjoining Bowood. He no longer need teach seven languages a day and give nightly lectures on a dozen different subjects. With £250 a year and a guaranteed annuity of £150 if relations were ever severed, stormy Priestley could now devote himself to science unhampered by lack of time or funds.

By 1774 the world had become well aware of Priestley the scientist. As an experimenter in gases none could surpass him. Already the *Transactions* of the Philosophical Society had become so crowded with his papers that he was writing a book on *Observations on Airs* detailing his numerous experiments. Queerly enough he had just received a book from a young Frenchman whose name he was beginning to hear frequently in scientific circles. This young Lavoisier had written an interesting book on gases in which many of Priestley's experiments were detailed and discussed. There were grave errors in the book. Some of the experiments were awkwardly done; some were mere repetitions of his own experiments. This was flattering but there was nothing which was not already known to Priestley except the conclusions that the calcining of substances was brought about by absorption of air rather than by the loss

of phlogiston. There was, concluded Priestley, nothing to this new theory of combustion.

The fame of Joseph Priestley as an experimenter in gases began in a strange way. During the brief six years of his dissenting pastorate in Leeds he says, "It was in consequence of living for some time in the neighborhood of a public brewery that I was induced to make experiments on fixed air." The wonder is that his congregation stood for such unclerical conduct for as long as six years. But the inquisitive Priestley was learning things. This gas from the brewery mash was fixed air, identical with that obtained by Black from chalk.

Soon, too, he had learned to collect gases for study by a new method. It was the method first used by Hales. Instead of the customary awkward pig's bladder which could be filled with the gas, he was using a vessel filled with mercury or water inverted over a trough of the same liquid. He could force the gas up into this container and hold it over a reservoir of the liquid. There was no danger of contaminating the gas and it could be kept for days or even months in its trap. Soon all chemists were collecting their gases with apparatus designed after Priestley's. He became the father of pneumatic chemistry. Priestley's method is still in use, huge gas tanks being designed on the same principle.

Priestley was not satisfied to stop with the observation that brewery mash produced fixed air. He dissolved the gas in water and tasted it; it had a pleasant tang, the tang he had noted in the natural waters of Spa. Why go to Spa; why not *make* Spa waters? Soda and acids produced fixed air; the latter could be dissolved in bottles of water for future use. Thus came the clever invention of soda water and, to the inventor, the famous Copley Medal of the Royal Society. Priestley had discovered nothing new, he had merely put to practical use the facts discovered by other men.

Priestley's next step in science had far greater scientific merit. He had read of the delightful experiment of Hales: a gas could be produced which, on mixing with common air, gave a new reddish gas. The great Dr. Hales got this gas by treating a certain mineral with spirits of nitre (nitric acid). But Priest-

ley had none of this particular mineral. In London, he put the question to Cavendish who suggested using common metals in place of the mineral. Back at Bowood House Priestley tried the experiment. It worked. He got the same gas; he named it "nitrous air." But with his insatiable curiosity he could not stop here. He shook the new gas with common air over water; the reddish fumes formed and dissolved in the water making the water acid, and the remaining common air was decreased in amount. Then he tested the remaining air with a burning candle; the candle went out. The residual air was noxious air (nitrogen). It must be air saturated with phlogiston, reasoned Priestley. He had removed the goodness from common air with his test and in doing so had removed about a fifth of the common air. So, he argued, he had removed that part of the air which was free of phlogiston. Could this test be used, then, to test the goodness of air? Soon, chemists everywhere were testing the goodness of common air with Priestley's nitrous test. They got the most surprising results. In crowded rooms, in great cities, in poor districts, the air was not good; in the country it was fine. This was what they wanted to believe and their results proved it. But Priestley could find no differences in the goodness of common air anywhere. Nor could the careful Cavendish. So accurate was the latter's work that there has been little occasion to change the conclusion since—except to change the terminology. He was measuring the proportion of oxygen and nitrogen in the air and not the amount of phlogiston.

Priestley, the great "amateur," was having fun with his gases which he was producing one after another with startling rapidity. He was entertaining the world of science with naïve and colorful descriptions of his experiments. He even recorded his mistakes, his failures and his train of thought when he was led astray. "I do not think it at all degrading," he said, "to the business of experimental philosophy, to compare it, as I often do, to the diversion of hunting, when it sometimes happens that those who have beat the ground the most, and are consequently the best acquainted with it, weary themselves without starting any game; when it may fall in the way of a mere

passenger; so that there is little room for boasting in the most successful termination of the chase."

Some historians have taken Priestley's own estimation of himself as the literal truth. But his works belie his words. No man, a rank amateur, by mere chance could have made the unique discoveries made by Priestley. He might by accident have made one, or possibly two—but a whole train of discoveries—never. It took a careful observer, a wealth of background, and a clever manipulator of apparatus to do what Priestley did. He never claimed to be a theorist. "More," he said, "is owing to chance, that is, philosophically speaking, to the observation of events arising from unknown causes than from any proper design or preconceived theory in this business." Again, historians have pounced on this statement to label Priestley a failure as a scientist.

Meanwhile in France, Antoine Lavoisier was taking an exactly opposite view. He had a preconceived notion and was searching, searching for links to complete the chain. He rarely experimented by chance. Each experiment, each step was a test for his great hypothesis and that only. Well might he characterize Priestley's works as a "web of experiments almost uninterrupted by reasoning."

But who can say which succeeded the better. Priestley made discovery after discovery. Lavoisier made none. Lavoisier fitted each discovery of Priestley into a beautiful new setting which Priestley could not even understand. Each was a supplement of the other. And in science, each needs the other; rarely does it happen that the peerless investigator and the astute theorist are combined in one personality, for the characteristics of the two are antithetical.

Priestley's ingenuousness in describing his experiments is vivid. The experiment is "charming," "delightful," "striking," "beautiful." The results are "startling," "amazing." "I was far from expecting"; "I was greatly surprised"; "I was struck"; "by chance I tried"; "I was utterly at a loss to account." Everywhere one is led to believe that the great Priestley's results were unexpected—and so they were—for he was

trying things no one else had thought of trying and getting results no one could predict.

From salt he got the sharp marine acid air (hydrochloric acid gas). From spirits of hartshorn he isolated the pungent ammonia gas. This gas gave not an acid but an alkali when dissolved in water. It was, therefore, termed alkaline air. Reasoned Priestley: if alkaline air and acid air are mixed, one might get neutral or common air. He tried it and was "amazed" to see a "beautiful" white cloud form which gradually settled down into a white powder. It was sal ammoniac. Today, stage and movie fogs are created in the same manner. By treating nitrous air with iron filings and "liver of sulfur" he obtained a most unusual gas. In it a candle burned vigorously, but a mouse promptly died. He called it diminished nitrous air. James Woodhouse, professor of chemistry at the University of Pennsylvania, tried this gas on his students. Soon, "laughing gas" parties were the vogue. Little did these early experimenters know that Priestley had discovered one of the most important anesthetic gases known to man, nitrous oxide or laughing gas. The mouse had not died in the gas; it was merely anesthetized.

Then, Priestley turned to that surprising gas already studied so carefully by Cavendish, inflammable air (hydrogen). It was the lightest of all the known airs. It was, in the opinion of Cavendish, phlogiston itself, for it burned violently in air. And it was driven forth from metals when they were treated with acids. If this were phlogiston it should, when heated with a metal calx, unite with the calx to produce a metal, reasoned Priestley. He tried the experiment; the calx changed into a metal and the inflammable air disappeared. Proof enough that this inflammable air was the long-sought phlogiston itself!

Then he mixed this supposed phlogiston with common air and passed a spark into the mixture; he was rewarded with a violent explosion and part of the air disappeared.

There was a mist on the walls of the vessel.

He noted this fact but gave it no further attention. Cavendish would, in another decade, grasp the real meaning of this mist, and Lavoisier would explain its full significance in his new system; it would form the last link in his great chain.

It is little wonder that Priestley was anxious to be at work on his airs this bright Sunday morning in 1774. He had a fine new lens "of twelve inch diameter and twenty inch focal length" —a poor lens beside the great Tchirnhausen monster which Lavoisier was wont to use. Nevertheless, it was sufficient for Priestley to make the greatest discovery of his career, the greatest single discovery of a century. He also had a sample of red calx of mercury, *mercurius calcinatus per se,* a powder formed by heating mercury in air just below its boiling point. Perhaps this substance would produce an air when heated in the focus of his lens. It might even give fixed air. He planned to see "what types of airs a variety of substances would give." But the startling results of his first trial were sufficient to hold his attention for months.

In France, Bayen had already heated the red calx of mercury and had got a gas. But he neglected to study it carefully; he called it fixed air. Priestley, the expert on gases, would never make this mistake.

Carefully, Priestley placed the red calx above the water in his inverted vessel, then focussed the sun's rays on the powder. Soon he had a considerable volume of gas in his trap. The gas did not dissolve in the water; evidently it was not fixed air. Perhaps it was mephitic air. A lighted candle would tell; if the candle were extinguished it was probably mephitic or noxious air (nitrogen). In his own words he tells the startling result:

"But what surprised me more than I can well express was that a candle burned in this air with a remarkably vigorous flame very much like that enlarged flame with which a candle burns in nitrous gas; but as I had got nothing like this remarkable appearance from any kind of air besides this particular modification of nitrous air and I knew no nitrous air was used in the preparation of *mercurius calcinatus per se,* I was utterly at a loss to account for it."

Priestley was surprised. Why? Not because the candle burned but because he had apparently gotten nitrous air from something he was convinced could not produce it. Why didn't he immediately put a mouse in it to see whether the mouse lived

or died? That would be proof enough. But he didn't. The path of the original investigator is devious. He was confused, satisfied that this air was nothing else than diminished nitrous air in spite of its source. Perhaps after all, his red calx of mercury was instead, red precipitate of mercury, a substance prepared by treating mercury with spirits of nitre. The two red powders were indistinguishable once prepared and the latter, prepared with spirits of nitre, might give him nitrous gas. "So far," he says, "was I from knowing what I had really found; taking it for granted that it was nothing more than [diminished nitrous air]."

Next, he turned to the red calx of lead (red lead, or minium). Perhaps the similarity in color led him to expect similar results. He would be the last to deny such a slim basis of reasoning. And he was not disappointed; the red calx of lead, prepared in a manner perfectly analogous to that of preparing the red calx of mercury, gave him the same gas. Now he was suspicious "that the *mercurius calcinatus per se* must get the property of yielding this kind of air from the atmosphere, the process by which that preparation and this of red lead is made being similar."

Though Priestley had made a startling discovery, he was wholly unaware of it. Bayen had missed it; Lavoisier had missed it; Hales had missed it; Boyle had missed it. All had passed by, blinded either by preconceived notions or by lack of investigative instinct. Priestley was blinded by neither. More than that, he had a full background of extensive work in gases to draw on. He was unbiased, unblinded and an "amateur," holding his net to catch the golden rain of fame which fell his way. In France was another "amateur"—"a farmer-general playing at science." He was biased and blinded by a notion. And in his net, too, would fall the golden rain of fame. To the Priestleys of science, accurate in observation, willing to try anything that comes to mind, goes the honor of discovering many new facts, of opening up many new fields to conquer; to the Lavoisiers, thoughtful, logical, fearless in their travel of new mental paths, willing to challenge the past, goes the honor of conquering these new fields, of coordinating the facts.

Priestley rubbed the end of his over-large nose and screwed up his small eyes as he weighed the problem. Where did this diminished nitrous gas come from? He was far from the truth, deluded by his own prejudices and it would be months yet before he discovered his error. In the meantime, he must leave the peace of his laboratory to accompany his patron on an extensive continental tour. The prospects were pleasing to the provincial Priestley who had never been beyond England's shores. They were particularly pleasing since Paris was to be included in the itinerary. There he could meet scientists about whom he had read, with whose works he was familiar, members of the famous Academy which had included him as a foreign member. He would like to meet Le Roy, Cadet, Condorcet, old Macquer, young Berthollet and, chiefly, Lavoisier. Priestley's modesty would not prevent his meeting these men on equal terms, for his fame was far greater than theirs and rested on secure ground. In fact, he might even enjoy being lionized a bit.

After Holland, Flanders and northern Germany, at last came Paris. Bashful, stuttering Priestley was to be seen at all the great assemblies and routs with his patron. But this was not what Priestley was looking for. He wanted to spend his hours with the philosophers. He begged to be excused from affairs of fashion. "Thenceforward, he spent his evenings with parties of literary and philosophical people who flocked to his Lordship's hotel or engaged him elsewhere. . . ." But even this lionizing wearied him in time. "I have," he said in a letter, "here had the opportunity of seeing many of the men who have the chief lead in the direction of affairs. . . . They are a set of philosophical men, whose object is freedom of commerce and universal peace. . . . I am quite tired of the idleness in which I spend my time here, and long exceedingly to be about my experiments."

Priestley found many men to his liking among the physiocratic school. He met Trudaine, Condorcet, Du Pont, Lavoisier, and others. And it was a happy group of physiocrats at this moment. The misreign of Louis XV and his mistresses had at long last come to an end. Smallpox had won. In the dark night of May 12, 1774, guards and pages had escorted a coffin,

containing all that was mortal of the scarce-mourned monarch, covered with quicklime, to its burial spot in St. Denis. "It was," said Besenval, "more like the transport of a burden of which men were anxious to be rid, than the last duties rendered to a monarch."

Du Barry was gone, so was Terray; his effigy hung on the gallows at Sainte Genevieve. Twenty-year-old Louis XVI and his nineteen-year-old Austrian queen, Marie Antoinette, sat on the throne of France. Young Louis was a liberal—so he thought. The exiled parlement of Paris was recalled and "honest" Turgot was the new Comptroller of Finance in place of the uncle of Madame Lavoisier.

Priestley's opinion of Paris was not flattering. "I cannot say," he said, "that I was much struck with anything except the spaciousness and magnificence of the public buildings, and to balance this, I was exceedingly offended by the narrowness, dirt and stench of almost all the streets." Nor was his opinion of the French people particularly flattering. "In general the French are too much taken up with themselves to admit of that minute and benevolent attention to others which is essential to politeness. This appears in nothing more than their continually interrupting one another in discourse, which they do without the least apology so that one half of the persons in company are heard talking at the same time."

Priestley, minister of the gospel, got the impression that most of the French philosophers were professed atheists. "On interrogating them on the subject I soon found that they had given no proper attention to it and did not know what Christianity was. . . . I always told them very freely that I could account for the infidelity by the very corrupted state of their established religion."

But for his work in science the French savants showed the greatest respect. Even Priestley was conscious of the feeling, for he naïvely wrote, "They could not possibly, however, show more respect to anybody than they did to me, especially on account of my *Observations on Air* which have engaged the attention of almost all the philosophers on the continent."

Priestley was not in Paris long before he made the acquaintance of Lavoisier. He soon became a frequent guest at the Lavoisier mansion in the Rue Neuve-des-Bons-Enfants. Here he saw a spectacular experiment and speaks of it in his customary superlative terms. "At Mr. Lavoisier's I saw with great astonishment the rapid production of, I believe, near two gallons of air from a mixture of spirits of nitre and spirit of wine . . . and when that ingenious philosopher applied the flame of a candle . . . it burned with a blue flame . . . he made the streams of blue flame extend to a considerable distance."

What Priestley's private opinion of Lavoisier may have been he never reduced to writing. To Trudaine he later wrote, "The world has great expectations of him and I doubt not that he will abundantly answer them." Again he spoke of him as "my excellent fellow labourer in these inquiries and to whom in a variety of aspects the philosophical world has great obligations." He was encouraging a young man, not speaking of his peer in science; he was a little condescending and just a little piqued. He had reason to be piqued. Lavoisier had mistreated his works, had made mistakes in interpretation and mistakes in translation of his papers. Lavoisier had attributed to him things he had never done and had twisted other results to suit his needs. In the preface of the second volume of his *Observations,* Priestley complained bitterly. "I am very sorry," he wrote, "to have occasion to insert in this volume a particular section on the mistakes that have been made with respect to my *Observations and Experiments* by several foreign philosophers. . . . For these mistakes foreigners may plead the want of a perfect knowledge of the English language and in some measure the plea may be admitted, though every person should take care to make himself fully acquainted with what he proposes not only to understand but to explain to others." His remarks were certainly pointed at Lavoisier. He listed four pages of mistakes and added "I shall not even think it worthwhile to note all the mistakes of Mr. Lavoisier."

Priestley was full of his new discovery of the gas obtained by heating the red calx of mercury. Everywhere he went he described in dramatic stuttering sequence his amazement at the

results. "I mentioned it," he said, "at the table of Mr. Lavoisier when most of the philosophical people of the city were present, saying it was a kind of air in which a candle burned much better than in common air, but that I had not then given it any name. At this all the company and Mr. and Mrs. Lavoisier as much as any, expressed great surprise." Priestley was careful to state in later years that he had frequently mentioned this new gas while in Paris. He was anxious that the world should know about it for on these words hinged the credit for the greatest discovery of a century.

When he questioned the possible origin of his red calx of mercury, Cadet offered him a sample about which there could be no question. Priestley carefully took this sample back to England with him. Strange fate! Lavoisier would use a sample from the same source. It was Cadet's red calx of mercury which would lead one of them to a great discovery, the other a correct interpretation of that discovery.

The momentous dinner was over. Lavoisier could cogitate on the new gas Priestley had announced. He could have rushed to his laboratory to repeat this experiment. But he didn't. No more than Priestley did he grasp the significance of this important clue, this last great link in the chain he was forging. He could see no immediate connection between this new gas, which appeared to be diminished nitrous air, and his problem of combustion. It would be a good half year before he came to realize any connection and even then he must wait for Priestley to show him the way more clearly. No, Lavoisier did not immediately surpass "his illustrious rival." He had much yet to learn of careful experimentation and accurate observation.

Back in England again, Priestley turned once more to his new gas. This time he used Cadet's sample of red calx and once more he got the strange gas. He shook it vigorously with water. If it were diminished nitrous gas it should absorb air and dissolve in water; the remaining gas should extinguish a lighted candle. But to his surprise "a candle still burned in the remaining air with a vigorous flame." Again, two days later he shook the same gas with air once more and "a candle

still burned in it as well as in common air." Now he was convinced that this gas could not be nitrous air. But of what it really was he was in ignorance. "I still did not suspect that it was respirable . . . so far was I from having any idea of this air being, what it really was, much superior, in this respect, to the air of the atmosphere."

Priestley was baffled. He could not bring himself to believe that this gas could have anything in common with the atmosphere. Every indication pointed to it, for the red calx of mercury was prepared by heating mercury in air. Could he not see that this mercury on heating absorbed a gas from the atmosphere which it gave up again on stronger heating? Looking backward, it would seem that even a schoolboy could see the simple answer. But looking forward from the time of Stahl, Priestley's blindness is easy to understand. He was a thorough and, in strange contrast to his religious views, an orthodox believer in phlogiston. A calx must be formed, not by the absorption of gas by a metal, but by the liberation of phlogiston. Perhaps *mercurius calcinatus* was not a true calx.

The reasoning of the great experimenter could carry him no further. Like a good scientist, he would let the problem simmer in his mind and return to it refreshed at a later date. "In this ignorance of the real nature of this kind of air I continued from this time to the first of March following," he said. In the meantime, he worked on vitriolic acid air. By March of 1775 he was back again on the baffling problem. By happy chance, and fresh from other work, he decided to try on this new gas his test used to show the goodness of common air. And to his vast surprise, he found that it gave the same red fumes which dissolved in water. Was this new gas, then, merely common air, "adventitious air," included somehow in the calx of mercury? It could not be diminished nitrous air and give this test. But now came an even more surprising result. He tested the remaining gas again with his test for goodness. The good air should be all removed by this time, leaving only noxious air. But no! Again his gas gave a fine test for goodness. Strange thing! Was this air even *better* than common air? Surely now the goodness must be all removed. Still the surprises were not over. On the

next day, again by "happy chance," he grasped a lighted candle and placed it in the remaining gas. "If I had not happened," he says, "for some other purpose to have a lighted candle before me, I should probably never have made the trial; and the whole train of my future experiments relating to this kind of air might have been prevented." The candle did not go out as he expected, but burned "even better than in common air." It *was* a happy chance. "I cannot, at this distance of time," he said, "recollect what it was that I had in view in making this experiment; but I know that I had no expectation of the real issue of it."

Poor Priestley! Once more his own words condemn him in the eyes of many historians. But Priestley had a reason for his experiment—a reason that flashed into his mind as a rare happy thought. Sheer randomness would have invited every other test but the right one. Priestley chose the right one instinctively and intelligently. His naïve words belie his clear actions.

So, this gas was not nitrous gas at all, it was common air—or perhaps even better than common air. It was "*at least* as good as common air." Since it was not nitrous air and since a candle burned vigorously in it, a mouse should live in it. He must have a mouse. Fortunately there were plenty available. By the eighth of March he had his "full grown" mouse. Grasping the little animal by the back of the neck, he thrust it up into the trapped gas and placed it on a dry platform. The mouse suffered no shock in its confined world of new gas. Patiently it investigated the confines of its limited perch, while Priestley as patiently sat by to watch results. In confined *common* air a mouse should live a quarter of an hour before the goodness of the air was used up. The minutes rolled by; a quarter of an hour passed; the mouse seemed perfectly content with its atmosphere. Fifteen more minutes and the mouse began to show signs of fatigue. The kind-hearted scientist removed the mouse and warmed it by the fire. Life quickly returned to the little creature.

The new gas was certainly respirable. The tiny unwilling experimentalist had proved that. Had this mouse used up all the goodness of the air? He tested the remaining air with his

nitrous test on the next day. It was still good air! And again, on the following day, it still gave the nitrous test for goodness. Once more the unwilling mouse went back into its trap with the same air which had already had its goodness reduced by three successive tests. Again the mouse seemed perfectly happy in its gaseous cage and was removed at the end of a half hour "quite lively and vigorous."

There could no longer be any question about it. This air was *better* than common air! And Priestley was forced, against his religious convictions, to the conclusion that there was a better air than that provided by nature. The new gas no longer puzzled him. It was not nitrous air; it was air purer than that found in the atmosphere. Common air, he argued, contained considerable phlogiston; animals could not breathe it in confined space for long without saturating it with phlogiston and rendering it completely noxious. But this new air was free of phlogiston, and animals could remain in it much longer before it became saturated with phlogiston. This air with the phlogiston removed Priestley called "dephlogisticated air."

Now the intrepid investigator was ready to breathe this new gas himself. "The feeling of it in my lungs," he said, "was not sensibly different from that of common air; but I fancied that my breast felt peculiarly light and airy for some time afterwards. Who can tell but that, in time, this pure air may become a fashionable article of luxury. Hitherto only two mice and myself had had the privilege of breathing it." But he adds a cautionary note and a moral warning: ". . . for as a candle burns out much faster in dephlogisticated air, so we might, as may be said, live out too fast, and the animal powers be too soon exhausted in this pure kind of air. A moralist, at least, may say that the air which nature has provided for us is as good as we deserve."

To Mitchell he suggested blowing a fire with this pure air to give a hotter flame. And with such a flame Mitchell was the first to melt the refractory platina. He suggested the use of the gas in certain respiratory diseases, "when the common air would not be sufficient to carry off the phlogistic putrid efflu-

vium." His reasoning was faulty but his gas is used today for just such diseases.

On March 15, 1775, he wrote to Sir John Pringle announcing the discovery of this new pure air. And on March 23, 1775, his letter was read before the Royal Society. It was the formal announcement to the world that Joseph Priestley had discovered an important new gas.

Though he was still tangled in the web of phlogiston; though he still thought there was some connection between this gas and nitrous air—for he said ". . . they [his results] afford some foundation for supposing that nitrous acid [gas] is the basis of common air . . ."—nevertheless, he had cleared up his major confusion. And he was careful in stating his conclusions; he added, ". . . it is possible that I may think otherwise tomorrow. It is happy when with a fertility of invention sufficient to raise hypotheses, a person is not apt to acquire too great attachment to them. By this means they lead to the discovery of new facts, and from a sufficient number of these the true theory of nature will easily result."

But for all of his careful conclusions, Priestley would never recognize the "true theory of nature." And for all of his decrying of attachment to hypotheses, he himself would remain so attached to the ancient dogma of phlogiston that he would never sweep it clear. On his deathbed, a self-exile in far-off Pennsylvania, he would hurl feeble defiance at the new theory of the Frenchman, the theory which his own discovery had made possible, the theory with which Lavoisier would sweep the last vestiges of phlogiston from the earth.

A New Theory of Chemistry is Born

"AND Mr. and Mrs. Lavoisier, as much as any, expressed great surprise." Priestley in later years would always have it thus. No one saw fit to deny the statement, least of all Mr. Lavoisier. Priestley had spoken of his new gas and his great surprise over it not once but many times while in Paris.

Lavoisier had every reason to be surprised, not because Priestley had prepared a gas from the red calx of mercury—he had done that himself—but because the gas, instead of being fixed air as he thought it should be, turned out to be, in Priestley's judgment, diminished nitrous air.

Just a fortnight before Priestley's arrival in Paris, he had, with Brisson and Sage, heated the red calx of mercury. Bayen claimed that the calx could be reduced to mercury without the addition of charcoal. Lavoisier had felt the need of checking this unexpected conclusion. Bayen was right; no charcoal was necessary. Then what, mused Lavoisier, furnished the necessary phlogiston for the process? In most reductions of this type, charcoal was supposed to provide the phlogiston to the metal. In his intentness on the supposedly greater problem, he had overlooked the lesser, the nature of the gas produced.

Now Priestley was telling him that this gas was probably diminished nitrous air. Bayen said it was fixed air. Who was right? He would have to check up once more. But why should the calx of mercury yield nitrous air? Lavoisier was indeed as surprised and as puzzled as Priestley.

Priestley and Lavoisier had been looking intently at the same experiment; Priestley saw one thing, Lavoisier another. The one was interested only in the gas produced, the other in

the process of calcination. Now, however, chance had given Lavoisier a new view, that of Priestley. And Lavoisier would take full advantage of that chance.

It was autumn in France; the foliage was at its best and it was time for M. and Mme. Lavoisier to pay their annual visit to M. and Mme. Trudaine at the great château near Montigny in old Brie. Far from the snarled affairs of the tax farm and the busy world of Paris, Lavoisier might take some needed rest. But, no. Each morning found the scientist and his host, the king's minister, busy at work over the laboratory bench. One thing they must do was to check up on Priestley's new gas. The gas was collected and given all the tests for fixed air—but it wasn't fixed air—a candle burned vigorously in it. Perhaps there were no mice in Trudaine's well-kept château; at any rate, the investigators failed to make this important test.

Back in Paris in November, Lavoisier secured another sample of red calx, this time from Cadet's supply. And Priestley had a sample from the selfsame bottle. In the same month the two great philosophers were working on the same problem with the same materials. But their conclusions were different. While Lavoisier was learning only that the gas behaved like nitrous air, Priestley was learning that he had been mistaken in his original premise. The gas was *not* nitrous air.

Then, each in his own mind reached a dead spot in the problem and each turned to other labors, Priestley to vitriolic acid air which he had first met with at Montigny and Lavoisier to inflammable air and spirits of nitre. But neither could long stay away from the intriguing problem. As though there were some unseen, unfelt bond between them, both men returned to the problem once more on the first day of March 1775. Priestley was ahead in the race; for it was a race, though neither was aware of the fact. Priestley knew he was not dealing with nitrous air—and now he was discovering that it was common air. Lavoisier was soon making a similar discovery in Paris. He tried the nitrous test and the gas behaved like common air, giving him the familiar reddish fumes. He placed a bird in the gas and the bird suffered no shock. Lavoisier thought he had discovered something Priestley did not know. This supposed

new gas was nothing but common air. Nevertheless, it was the most important key he had yet found for his problem of calcination. And he could now fit the parts of his puzzle together with some precision and assurance.

Back in England, Priestley had not stopped. He was going one step beyond the Frenchman and thus assuring himself of the unquestioned honor of discovering the most important and most abundant of all elements, oxygen. He was discovering that this new gas was *far better* than common air; and he was naming it "dephlogisticated air."

While experimenter Priestley was discovering this remarkable fact, theorist Lavoisier was at last coming to understand the puzzling relationship of fixed air to common air. He heated red calx alone and got common air. He heated it with charcoal and got fixed air. And at the same time the charcoal disappeared. He could see the answer clearly now; the charcoal united with the common air lost by the calx to give fixed air, and so, fixed air was not an elementary gas at all; it was a combination of charcoal with common air (carbon dioxide). And calcination was nothing more than the union of common air with metals. Of course there should be an increase in weight! When this air was given forth from the calx by heating, there was a loss in weight and the air came out better, more pure, than it went in. Burning, then, was naught else than the union of common air with materials containing charcoal or carbon, and the gas which was always produced was fixed air. His dream of a revolution in science was at last becoming a reality.

These conclusions would not go unchallenged, he knew, but he was ready now to fight for his theory. He must hasten to set his conception before the world before someone else should do so ahead of him.

Before the Academy at the *rentrée publique* on April 26, 1775, he presented his famous memoir "on the nature of the principle that combines with metals in calcination and increases their weight." The great, mysterious principle was none else than common air. Philosophers knitted their brows as they tried to follow the reasoning of the speaker. Even the great

Macquer, staunch friend of Lavoisier, would spend many hard hours over the problem of synthesizing the two opposite theories—but he would eventually fail. It couldn't be done. If one theory was right, the other must be wholly wrong.

But Lavoisier's troubles were in no sense over; they had just really begun now that he was coming boldly into the open. The first trouble he must face was Priestley. He had failed even to mention Priestley in his famous memoir. Was it his ethical duty to do this? Priestley had told him of a gas which *appeared to be nitrous air*. Lavoisier had corrected that conclusion to his own satisfaction through his own experiments. What, then, did he owe Priestley? He owed Priestley the courtesy, at least, of publicly announcing that the Englishman had called his attention to the importance of the gas obtained from red calx. His besetting sin, failure to give credit, was tripping him again.

Priestley's letter announcing his new gas, dephlogisticated air, was read to the Royal Society on March 23; Lavoisier's memoir was read to the Academy on April 26. Neither philosopher knew what the other had said. Priestley would, however, know first what his "fellow laborer in these inquiries" had said, for Lavoisier saw to it that his own important document was published in Rozier's *Journal of Physics* in May, while Priestley's work in detail would become available only in the second volume of his *Observations* which would appear later in the year. Priestley was hard at work on the manuscript of his new volume when he received Lavoisier's memoir, but he took time off to learn what his "fellow laborer" had said. As he perused the pages covering the work on red calx of mercury, his indignation rose. Nowhere could he find the slightest mention of his name. Then his intense indignation changed to some amusement as he realized that the Frenchman, in his haste, had missed the vital point. He was calling this gas common air. Priestley knew better.

Now he would have an opportunity to give his important young friend some impersonal advice on the ethics of science and on his own shortcomings. The manuscript of *Observations* was still unfinished; the advice could be incorporated in the new volume. First, he made certain that his important conversa-

tion with M. and Mme. Lavoisier in Paris would never be forgotten or overlooked: he repeated it in the book. Then, he called careful and precise attention to the many mistakes Lavoisier had made in his own book. And, finally, he proceeded to chide his young friend in unmistakable terms. "There is not," he wrote, "in the whole compass of philosophical writing a history of experiments so truly ingenuous as mine and especially the section on the discovery of dephlogisticated air which I will venture to exhibit as a model of the kind. I am not conscious to myself of having *concealed* the least hint that was suggested to me by any person whatsoever [and on page 121 he gave Lavoisier due credit for the experiment he had seen performed in his laboratory]. . . . I have hitherto made the most early publications of my observations . . . and though this conduct has exposed me to some inconvenience I am not yet discouraged . . . and I hope through life [to] persist in the same habit of the most open and unreserved communication private and public." Then he called Lavoisier's attention to the experimental errors he had made on the new gas. "When he sees this volume of mine, he shall, I doubt not, be convinced of the imperfection of his theory and of the mistake which he has been led into by means of it." Priestley's results would, indeed, convince Lavoisier of the "imperfection" of his theory but not in the manner that Priestley imagined. He would not discard the theory but through Priestley's observations would be led to a more complete and perfect theory.

Priestley was dealing with an intellectual giant whose clear logic and powerful reasoning he would never be able to comprehend. Priestley was a great experimenter but a poor theorist. "There was no ruling purpose behind his work and there was no austerity in his thinking. Ultimately, Lavoisier must surpass Priestley. He was in earnest about what Priestley passed over lightly and amiably. His work was inspired by a great motive and controlled by a principle."[7]

Priestley was quite willing to state his grievance to any who would listen. To Thomas Henry, publisher of the English translation of Lavoisier's book, he wrote: "He ought to have

[7] *Ibid.*, p. 60.

acknowledged that my giving him an account of the air I had got from *mercurius calcinatus* and buying a quantity of M. Cadet while I was in Paris, led him to try what air it yielded, which he did presently after I left. I have, however, barely hinted at this in my second volume."

To Trudaine, Priestley wrote in quite a different vein in November. He was sending the sheets for his new book trusting that Trudaine as Director of Posts and Highways would expedite their transmittal to the French translator, Gibelin. There was no hint that Priestley was grieved over Lavoisier's conduct, but there was significant praise. "Please to present," he wrote, "my most respectful compliments to Mr. Lavoisier whose name is several times mentioned in the course of the work and especially at p. 121. The world has great expectations from him and I doubt not he will abundantly answer them." Priestley was specifically calling Trudaine's attention to the passage in which Lavoisier was given credit for a certain experiment which Priestley saw him perform. He "allowed Trudaine to discover for himself the passages in which Lavoisier was mentioned in much less complimentary terms."[8] There was little doubt but that Trudaine would soon bring these passages to the attention of Lavoisier. Was Priestley as naïve as history paints him?

Lavoisier soon became aware that he had missed an important discovery. He had missed finding the most important link in his whole chain; he had barely missed discovering the most important of all the elements, the element to which he would soon even give a new name. If Priestley was right, it was not common air which played the rôle in calcination but only one constituent of this common air. And the other constituent was mephitic air (nitrogen) in which candles could not burn, life could not exist. Had Lavoisier but stuck to his original idea, expressed in 1774, that common air was composed of two constituents he would have found no need now to reverse himself.

Now he was busy again, testing this gas once more, not with hasty work but with careful, methodical, and exhaustive experi-

[8] Oesper, Ralph E., "Priestley, Lavoisier and Trudaine de Montigny," *Journal of Chemical Education*, vol. 13, p. 403, 1936.

ments. He burned candles in the gas, tested it successively with the nitrous test, placed animals in it and he became convinced that Priestley was right.

Soon Antoine Lavoisier was performing his most celebrated experiment.

In a retort with a swan-like neck he placed a weighed portion of mercury. The open neck of the retort was placed in air trapped in an inverted vessel. For ten days the mercury was gently heated. A red powder gathered on its surface and at the same time, the volume of the trapped air decreased. The mercury was obviously taking air from the trap to form red calx, and the quantity of air diminished "about" one-fifth. Now he weighed the calx and measured the amount of air used up. This amount matched the increase in weight of the metal. The remaining air extinguished candles and killed mice. It was noxious air. Next, he removed the red calx to a smaller retort, heated it strongly and collected the evolved gas over a water trap. The loss in weight of the calx in this operation matched up with the weight of gas he obtained. And the gas was Priestley's dephlogisticated air. Candles burned vigorously in it; mice cavorted freely in it; it gave the nitrous test as often as he could wish. Finally, he mixed some of this pure gas with some of the mephitic gas and he once more had common air. He had taken this "eminently respirable air" from the atmosphere, combined it with mercury, then released it once more, free from the other constituent of atmosphere. It was the confirming step in the great new theory. The problem, at long last, was solved. There were, after all, two constituents in the atmosphere: one, a pure air (oxygen); the other, mephitic or noxious air (nitrogen). In one remarkable experiment Lavoisier had established the truth of his theory.

He was willing now to offer some sort of apology to Priestley but he could not bring himself to the point of renouncing all shreds of claim to the discovery of this new gas. He said in 1776: "Perhaps, strictly speaking, there is nothing in it of which Mr. Priestley would not be able to claim the original idea; but since the same facts have conducted us to diametrically opposite results, I trust that if I am reproached for having

borrowed my proofs from the works of this celebrated philosopher, my right at least to the conclusions will not be contested." It was not a graceful apology. Lavoisier wanted some claim to this discovery upon which the whole structure of his new theory of chemistry rested. Everything else in it was his own except this one discovery. He could explain combustion, calcination, fixed air, formation of acids, and even the life processes, but this one thing he could never have. Posterity has denied it to him. He was quite willing that Priestley be granted priority if he could only have the honor as an independent discoverer. In 1782, he wrote, "This air which Mr. Priestley discovered at very nearly the same time as I and I believe even before me. . . ." Still later he was presenting his claims in the words, "This air which Mr. Priestley, Mr. Scheele and I discovered at about the same time. . . ." The decision of history is just. Lavoisier did *not* discover oxygen. But he named it, understood it, and pointed out its importance in the affairs of man and nature, things which Priestley, its discoverer, could never have done.

But even though Priestley would never have to share the honor of his discovery with the Frenchman, he would, nevertheless, have to share it with another man, a Swede. And he would find that this diffident Swedish apothecary had not only preceded him in the discovery but had prepared the gas from at least a half-dozen sources before that bright sunny day of August 1, 1774. But like Priestley, Carl Wilhelm Scheele was wedded to the theory of phlogiston; he would never clearly understand this gas which he unearthed and appropriately named "fire air."

Like Priestley, Scheele was an experimenter. His boyhood, passed in Stralsund, capital of Swedish Pomerania, was uneventful as was his whole short life outside the realm of chemistry. He never acquired wealth and never sought fame in the forty-four years of his existence. "One need not eat more than enough," he wrote to Bergman in his later years, "and if I can find my bread in Köping, there is no occasion to seek it elsewhere." So he remained in his Köping apothecary shop.

No scientist in a century has made more new discoveries in chemistry than Scheele. Yet, even his own countrymen were slow to appreciate his genius. His first two papers to the Swedish Academy were rejected (because of his awkward language) on the suggestion of Bergman, who was later to become Scheele's closest friend. Scheele felt the rebuff keenly and was slow to apply again for recognition. But before the close of his short life he was the Swedish Academy's most illustrious member, foreign member of the Royal Society and the French Academy, recipient of a government pension, and the foremost chemist of Sweden. He was the olny apothecary ever to become a member of the Swedish Academy. He remained in the town of Köping, struggling to build up a simple trade in drugs, a trade that he might leave to his housekeeper, widow of the former apothecary of the town. On his deathbed he married this widow so that the business might once more be restored to her family.

His greatest memoir on *Air and Fire* was ready for publication in 1775. Priestley was then working on the second volume of his *Observations;* Lavoisier had just read his famous memoir on calcination. There were, however, delays in publication. Scheele complained to Bergman in 1776, "I have thought for some time back and I am now more than ever convinced, that the greater number of my laborious experiments on fire will be repeated, possibly in a somewhat different manner, by others, and that their work will be published sooner than my own, which is concerned also with air. It will then be said that my experiments are taken, it may be in a slightly altered form, from their writings. I have to thank Swederus [the publisher] for all this."

Scheele had no doubt heard something of Priestley's work or of Lavoisier's, though there was little scientific exchange between England or France and Sweden. But Scheele need never worry. No one would ever accuse him of plagiarism. His works were too prolific, his methods too novel, and his life too open ever to suggest such a possibility. But not till 1777 was Scheele's book on *Air and Fire* published, and not till then did the world know that Priestley must share his honor with

Scheele. Both were independent discoverers of oxygen. There was honor enough for both, however, in this great discovery.

Though Scheele lived till 1785 he never adopted Lavoisier's new theory. He was poor at logic and mathematics; he rarely made use of the balance in chemistry and was little interested in theoretical problems. His poor attempts at theoretical interpretation of his own experiments bear mute witness to this. As an investigator, he was superior even to Priestley in the wide variety of problems he attacked. As a generalizer he was no match for Lavoisier.

Though Lavoisier opened his first subtle attack against phlogiston as early as 1774 in an anonymous article appearing in Rozier's *Journal* and had followed it up with his decisive memoir in 1775, he was still too doubtful of the strength of his new theory to hazard a bold and open assault. But after he had carefully checked Priestley's work and had received the verification which he found in Scheele's work, he needed no longer to hide behind the draperies of the old theory.

In 1777 at an open meeting of the Academy he repeated his memoir of 1774 on the calcination of metals. An honored and interested guest at this meeting was the Emperor Joseph of Austria, liberal-minded brother of Marie Antoinette. In the spring of 1778 he repeated the famous memoir of 1775. The intervening years had provided the opportunity to recast his ideas on the basis of Priestley's discovery. Unfortunately, these carefully revised memoirs have gone down in history as the original memoirs, owing to the lax habit of the Academy in publishing its transactions several years late. The year *1778* and not 1775 marks the first decisive victory in the overthrow of phlogiston and the beginning of the new theory of combustion and respiration. It marks the introduction of Lavoisier's new term, oxygen, to describe Priestley's dephlogisticated air. This gas, argued Lavoisier, was the principle which combined with such non-metals as phosphorus, sulfur, and carbon to convert them into acids. Hence, it was the acid-forming principle. From the Greek he coined the word oxygen (oxus, acid: gennao, I beget). Here, strangely enough, Lavoisier made the

one major mistake in his theory. Oxygen was not the acid-forming principle. He would discover this later to his utter surprise.

Lavoisier had a new theory and the new theory had one supporter, Antoine Lavoisier. The whole world of science was hostile, antagonistic, sceptical. Most hostile of all were the chemists of the Academy. Even Macquer, staunch friend of Lavoisier, was afraid of it. To Guyton de Morveau he wrote, "M. Lavoisier frightened me for a long time with the surprising discovery which he has carefully kept to himself and which seemed to overthrow the phlogiston theory. His assurance quite upset me. Where would the old chemistry be if we were forced to rebuild it completely? I, for one, would have forsaken it. And now, M. Lavoisier brings his discovery into the open and I assure you that it gives me a sinking feeling." Macquer did not forsake the camp. He attempted instead to integrate the old with the new by maintaining that phlogiston was the matter of which light was composed rather than the matter of heat. To this supposition Lavoisier retorted: "It is Macquer's theory, not the phlogiston theory."

He had the phlogistonists fighting among themselves over their own mistakes. Then he delivered his most vigorous attack. "The partisans of Stahl's doctrine," he wrote, "are continually in . . . difficulties. If they are asked what happens when mercury is calcined in vital air [oxygen], the English philosophers reply that the phlogiston . . . is released from the metal, combines with the gas and changes it into fixed air or phlogisticated air. But this . . . is absolutely contrary to the facts. When the experiment is performed in perfectly pure vital air, the air can be absorbed to the last bubble. . . .

"All these reflections confirm what I have advanced, what I intended to prove, what I repeat again: chemists have made an imaginary principle out of phlogiston which, not strictly defined, fits all explanations required of it; sometimes it has weight, sometimes it has not; sometimes it is free fire, sometimes it is fire combined with earth; sometimes it passes through the pores of vessels, sometimes these are impenetrable to it; it

explains at one and the same time causticity and non-causticity, transparency and opacity, color and the absence of color. It is a veritable Proteus that changes its form every minute.

"It is time to lead chemistry back to a stricter line of thought, to strip the facts of this science of rationalization and prejudice; to distinguish fact and observation from system and hypothesis, in short, to define chemical knowledge precisely so that those who come after us may start from such definitions and go forward confidently in the advancement of the science. . . .

"I do not hope that my ideas will be adopted at once; the human mind inclines to one mode of thought and is slow to change; it is time [however] to confirm or reject the opinions I have advanced."

Could Lavoisier hope for victory against an utterly hostile world of science; could he demand that chemists trained to the school of phlogiston throw off their ancient learning to start once more from the beginning? It was asking much. He did not ask it; he demanded it. Reason and truth demanded it. The facts were attested to by experiments, the convincing truth of which could not be denied. Yet, no chemical work of any import written as late as 1779 even so much as mentioned the work or the theory of Lavoisier.

The struggle to perfect the new theory was about over, but now must come the even greater struggle to induce a sullen world of science to accept this vision. With pitiful slowness converts entered the new camp, became imbued with the spirit of the master and went forth to preach the new truths.

First to enter the new camp and stand squarely beside Lavoisier and his new theory was Laplace, renowned astronomer and mathematician. Then followed a few more physicists and mathematicians. Still the chemists hung back. Finally, at the *rentrée publique* of the Academy on April 6, 1785, the young chemist, Claude Louis Berthollet, stepped forward publicly to accept the new doctrine. It was the first break in the ranks of the chemists. A year later attorney Guyton de Morveau, great philosopher-chemist of Dijon, joined the little group. In 1787,

the fourth member of this notable quartet, soon to be spoken of in England with mistrust and disdain as "The French Chemists," entered the cause. He was Antoine Fourcroy. These four horsemen would ride rough-shod over the old chemistry; one of them would, in the end, forget his master.

Life at the Arsenal

WHILE Antoine Lavoisier was conducting his battle against phlogiston as a scientist, he still found time to live the life of an active citizen. He was no recluse confined to a laboratory bench, no eccentric barred from polite society by a queer personality. He was a well-informed, active man of his day, casting his lot by preference with the liberal thinkers, the protestants of autocracy.

With Marie he found time to visit his father's pleasant estate at Bourget. Nothing brought him greater satisfaction than hours spent with this father whose life had been lived with selfish devotion to an only son. Frequently, Jean Lavoisier accompanied his son on missions to the provinces. And frequently, joined by Marie, the three travelled by coach over the same road the king's postillion had ridden two centuries earlier to the great curving forest of Villers-Cotterets there to renew faith in a sturdy ancestry.

It was a severe shock to Antoine to receive word in the late summer of 1775 that Father Jean was desperately ill at Bourget. Hastening to his father's bedside, Antoine found that apoplexy had done its cruel work. At the age of sixty, Jean Lavoisier was forced to a bed from which he would never rise again. On the fifteenth of September, there gathered at the bedside of Father Jean, Antoine, Marie, and Aunt Constance. The end came mercifully to still the pains of a crippled body. Jean Lavoisier was denied the supreme joy of witnessing his only son's rich reward of success; but with it he was also spared much sorrow.

One more tie to the past was broken for Antoine. More and more he would find himself turning to the family of Marie for companionship. In Jacques Paulze, and his two stalwart sons, Christian, assistant to his father in the tax farm, and Balthazar, linguist, writer and traveller, Antoine would find intellectual friendships he needed.

From the provinces on one of his innumerable trips Antoine wrote to his Aunt Lavoisier of his father's death, "You know the tender friendship which always existed between us and the mutual confidence we had in one another and you can judge how it hurts me. He has done great good and no harm. I hope that his spirit of integrity wil lalways serve me as a true guide in life and death." Again he wrote, "He was less a father than a fine friend. The tenderness and confidence which always existed between us made him most happy."

In six years Aunt Constance, who had made her home with Antoine and Marie, would follow Father Jean to the grave, leaving to her cherished nephew her little fortune, a fortune which was scarce needed but which was accepted along with that from Father Jean and used wisely and generously in the welfare of science, friend, employee and nation. Constance Punctis, quiet, gentle, and wedded only to the task of caring for her sister's children, shone by reflected glory; her life was lived in the background of greatness as she watched her beloved nephew steadily climb the ladder to fame.

The great friend of Lavoisier's youth was Trudaine de Montigny. Between the two men there existed one of those rare friendships untinged with jealousy or envy. Trudaine had set up, at Montigny, a model estate on a democratic pattern. Old age pensions were a matter of course, and there was no need for unemployment insurance. There, Lavoisier learned the principles of benevolence and scientific agriculture which he would later employ so successfully on his own estate at Fréchines. In the laboratory the two men pondered over scientific problems by candlelight far into the night while Lavoisier advised his host on the construction of the great Trudaine lens or instructed his friend in the principles of chemistry. With the early death of Trudaine in 1777, this fine friendship was ended.

There was another rare friendship which Lavoisier formed early and kept throughout life. It was his friendship with the unassuming druggist, Pluvinet. Many times Lavoisier would drop into the shop of Pluvinet to spend hours working on the preparation of some substance, talking over the efficacy of drugs, the futility of medicines, the development of his own new theory or the deplorable state of the nation. Though Pluvinet was never one of the distinguished guests at Lavoisier's famous dinners, he proved to be, nevertheless, one friend in a thousand.

Lavoisier was a great admirer of Jacques Turgot. He had, with the rest of the physiocrats, become convinced that the only salvation of France lay in a governmental economy, stimulation of trade, and equalization of taxes. It was, therefore, a joyous day for him when he received news that the new king had appointed Turgot Comptroller of Finance in place of the unscrupulous Abbé Terray. Turgot was one of the few men in France who had the vision and the strength to coordinate and carry through the social, economic, and political reforms needed to save the nation from revolution.

There were plenty who advised the monarch against appointing "Honest Turgot" to office. He was a reformer; he would upset the entire status quo with his visionary schemes; he would stir up the rabble; he was no diplomat and men were ill at ease in his presence. But Louis, young and anxious to become a popular and liberal ruler, refused to heed the advice. "They may say what they please," he replied, "but he is an honest man." To Turgot he said, "Fear nothing, I shall always support you."

Turgot went into office under no delusions. He knew that he would "be feared and even hated by the greater part of the Court, by all who look for favors." But he trusted the young king and counted on his support. The joy of all liberals was expressed by aged Voltaire; and for once there was no cynicism, no irony in Voltaire's pen. "It seemed to me," he said, "as if a new heaven and a new earth had made their appearance."

Turgot started out with full zeal and energy. He was scarcely in office before he was advising the removal of the elaborate

and costly trappings surrounding the feudal ceremony of the coronation of the new king. In that first contest Louis failed his minister.

Then Turgot turned his attack on the hated corvée which dragged peasants from their plantings and harvestings to work at highway-building even while crops rotted or lands went unplanted. For this he received scant thanks from the landed proprietors on whom the new highway tax would fall. He stimulated commerce through free trade in grain only to gain the hatred of trade guilds throughout France. He fought for real freedom of worship and made a mortal enemy of the established church. He refused the right of the queen to draw sight drafts on the treasury and Marie Antoinette joined in the attack on the unpopular Turgot. He fought to remove the royal *pensionnaires* from the overburden of the tax farm, and the royal family whispered in the king's ear that Turgot was a troublemaker. He fought to increase the revenue of the state from the farm, and the farmers—all except Lavoisier, Paulze and their little group of reformers—resisted all his efforts and advised his dismissal. He recovered one hundred thousand crowns of Terray's ill-gotten gains and turned the sum over to the ill-equipped hospitals of Paris.

Wrote the Swedish minister to his king, "M. Turgot finds himself opposed by a most formidable league, composed of all the nobles of the kingdom, all the parlements, all the financiers, all the women of the court, all the priests." Turgot was not a diplomat: "He did not know how to make allowances for the weaknesses of men, still less for their vices." Condorcet, his faithful friend and follower, said of him, "Public opinion had no influence over him."

In vain did Turgot attempt to hold the king to his promise of support. "Give me ten years," he said, "and you will see this chaos take distinct form, you will not recognize the country, so great will be its improvement." Louis could not stand ten years of such pressure, he could not stand even one. Two months after he declared dramatically, "There are only M. Turgot and I here who love the people," he signed the order dismissing his

stormy comptroller. Five years later, in 1781, Turgot died unmourned by those he had attempted to save.

With Turgot's downfall came also the fall of Du Pont and Malesherbes. The philosophers were out of office. The most eminent and upright lawyer of his day, Malesherbes was a daring reformer. He dared suggest fiscal reform for the nation. He dared more: he dared suggest the calling together of the ancient but seldom used assembly of the people, the States-General, to reform the taxes. He dared oppose his king's right to incarcerate innocent men to the Bastille. His first act as minister was to enter his carriage, ride to the Bastille, and, with a flourish for the public, order all political prisoners freed. When he resigned his ministry in disgust, it was with the parting thrust of Louis lingering in his ear, "How fortunate you are! Would that I could retire!"

Turgot's reforms soon followed him to oblivion. The hungry horde rushed to the treasury doors once more. In less than a year Turgot's treasury surplus had disappeared in the hands of his successor, M. de Cluny. Only the death of De Cluny prevented a further orgy of spending. Then came Swiss Protestant Necker, the financier from Geneva with his grandiose schemes for saving France from bankruptcy by borrowing. Though not eligible to be appointed minister or appear before the king, since he was a Protestant, M. Necker, nevertheless, virtually held the office of comptroller. He had the tact and diplomacy which Turgot lacked—but not the vision. He had the confidence and support of thoughtful financiers even when he drove a hard bargain with the tax farm—but he faced the same powerful combination of forces which brought down Turgot. He was a financial juggler afraid to face the consequences of real reform.

Though not politically prominent, Antoine Lavoisier had done all in his power to support and strengthen the ministry of Turgot. His position was a peculiar one. The farm fought Turgot's tax reforms and was an important factor in securing this unwelcome minister's dismissal. Lavoisier was at heart a physiocrat, believing in Turgot's reforms. Did he stand, then, with Turgot or with the farm? We know only that Turgot

trusted him. That, and his own expressed views, place him on the side of Turgot.

The most important problem which Turgot entrusted to Lavoisier was that of the manufacture of gunpowder. France had gone down to defeat in the Seven Years' War a decade before, partly because she lacked gunpowder with which to continue the war. She lost her colonial empire in America in 1763 partly because there was graft and corruption in the making of powder, because the monopoly or *ferme de poudre,* having in its hands entire charge of the making, distributing, and selling of powder, was composed of a group of financiers interested only in making money. None of the directors of the powder farm knew how to make powder and, furthermore, none cared. The price of powder had risen beyond all bounds.

With his sound business training, his adeptness as an organizer and his scientific genius, Lavoisier was the ideal man to bring order to this chaotic industry. Turgot and Lavoisier discussed the matter at length. The solution was to end the private powder monopoly and institute a government monopoly with commissioners in charge responsible to the government.

No time was lost in putting Lavoisier's ideas into operation. Four commissioners, Babaut de Glatigny of the former farm, Le Faucheux, director general of operations under the former farm, Clouet, commissioner of powders at Verdun, and Lavoisier, "well known for his work in chemistry, his technical ability, integrity and capacity exhibited in his work in the *ferme générale,*" were appointed. It was Lavoisier who was to become the real director of the powder commission. The gunpowder of the day was essentially that described by Roger Bacon in the mystic verbiage of alchemy as early as 1250. The essential ingredients were saltpeter, powdered charcoal and sulfur. Five centuries had changed only the proportions of the mixture, the purity of the substances and the mechanical means of producing explosions. Of the three constituents, saltpeter was the most difficult to obtain. All the world was searching for it. Some countries had established beds where refuse and excreta might be dumped for nature to work over into saltpeter.

But France still depended on the precarious supply which scattered farm animals might provide.

All over France roamed the gatherers of saltpeter, digging into every farmer's manure pile, searching henhouses, pigeon coops and pigstys. Even the homes were searched, for farmers might leach out their own saltpeter to hold for a high price. Obnoxious by profession and smell, these gatherers were unwelcome visitors in any village, for they held the right to search all homes or barns.

With the advent of the new powder commission came a change of method. The toll tax levied on villages for transportation was removed. Charges against villages for lodging and wood were greatly reduced and the right to search private premises removed; the workers were better paid. Curiously enough, these changes resulted in increasing the production of saltpeter. Those peasants who grumbled about the right of search now opened their premises to the gatherers.

Then Lavoisier turned his attention to methods of increasing the yield of saltpeter. He travelled the country studying deposits of saltpeter in chalk beds. The Duc de la Rochefoucauld called his attention to nitre in the lime deposits on his estate. He studied the problem of artificial nitre beds; he corresponded with savants in other countries seeking information; he induced the Academy to offer a prize for the best paper on methods of producing saltpeter. All applicants for positions in the department of powders had to pass civil service examinations. He issued a manual of instructions to subcommissions in the cities of France on the preparation of saltpeter, a manual which was reprinted during the Revolution without Lavoisier's name.

This unbounded energy brought results. In less than five years the production of powder approached the two-million-pound mark; within twelve years it had risen to the four-million mark with five million pounds stored away waiting for the armies of the Revolution. The powder commission saved the government twenty-eight million livres in fourteen years. Lavoisier had well earned his income from powders, fifteen thousand livres a year.

But he was not through yet. It was important to increase the efficiency of French powder. It should be the best in the world, not the poorest. By changing proportions, purifying the saltpeter, mixing the ingredients more thoroughly, he soon had a powder which was doing its deadly work at two hundred fifty yards. By 1779 the English soldiers were complaining bitterly about the long range of French guns. They had good cause to complain.

The American colonists, however, had good cause to rejoice that Antoine Lavoisier was commissioner of powders. American powder was poor, ill mixed, improperly dried and wholly undependable. American sharpshooters had to stalk the British troops like Indians to get within shooting range, and every shot must take its toll. With the advent of French powder all this was changed. The appointment of Lavoisier to his post came just in time to assist America in her struggle for independence.

As commissioner of powders, Lavoisier took up his new quarters in the grim old Arsenal of Paris. In 1775, Marie and Antoine said good-bye to their comfortable home on the Rue Neuve-des-Bons-Enfants. The laboratory equipment was carefully moved across town and set up in the spacious quarters provided in the Arsenal. Here, around the corner from the notorious Bastille, the Lavoisiers would live for sixteen years. To the laboratory in the Arsenal would come the great scientists of the world to meet and talk with the famous Lavoisier. There would come also young men fired with enthusiasm for science, men who would have the honor of working with Lavoisier in his laboratory. If they were penniless it mattered not. The generous purse of the Lavoisiers would be opened to them. They would find their way into good positions through the influence of the master. They would shine in his reflected glory—till the world turned on him.

An invitation to dinner in the Lavoisier apartment at the Arsenal was something every aspiring young scientist prized, for it gave entrée to the best circles of science and liberalism. Here one might see and hear: Laplace, suave, smooth mathematician, always eager to be on the right side politically; La-

grange, equally famous in mathematics but depressed with life, "staring absently out of a window, his back to the guests who had come to do him honor";[9] Turgot, still hopefully dreaming of an enlightened France; Malesherbes, ever optimistic; Du Pont rising hopefully through the ruins of one political career toward another; Quaker Franklin, minister extraordinary to the French court and idol of all the women of Paris; Condorcet, coldly polite, lost to mathematics and turned to politics; Berthollet, avid investigator in chemistry who would live to become the intimate of an emperor; Monge, geometrician, scientist and soldier, one of the few men in France who would dare to tell Napoleon the brutal truth; Macquer, greatest of the old-school chemists; Le Roy, intimate of Franklin; D'Arcet, in charge of the great Sèvres pottery works; Guyton de Morveau from Dijon, who was destined to become a leader in the new chemistry; Fourcroy, eloquent teacher who would one day become a powerful agent of the Revolution; Bailly, astronomer, who, by strange political sifting, would become mayor of Paris.

Among the noble guests were to be found the enlightened Duc de la Rochefoucauld, generous patron of science, no mean scientist himself, and leader of every liberal move; Duc d'Ayen, father-in-law of the dashing La Fayette, and one-time president of the Academy; Duc de Chaulnes, who once entered a closed cabinet in which charcoal was burning to study the effects of the gas—and was revived by his valet. From the farm came the liberals, Paulze, Borda, Creutz, and D'Arlincourt. From the Academy came many lesser lights and younger men, Bucquet, Cadet, Vandermonde, Cousin, Meusnier and others. If there were foreign philosophers in Paris, they were certain to receive an invitation. From time to time there appeared Blagden, secretary of the Royal Society of London; Magellan, friend of Priestley; Watt, great inventor; Ingenhousz, physician to the Emperor of Austria; Fontana, famous for his work on the venom of snakes; Tenant, who would apply Berthollet's discoveries to the problem of bleaching; Hassenfratz, Jacquin, Krantz, Mayer, and many others.

[9] Bell, E. T., *Men of Mathematics*, p. 166, New York: Simon and Schuster, 1937.

The Lavoisier salon was fast becoming a center of science and advanced thought. In science, discussion turned around the new theory of the host. Many of the guests found the food highly acceptable but could not swallow their host's theory of combustion. They found, however, no less cordial a welcome because of that. There were discussions on the fads of the day. The curative effects of the animal magnetism of Mesmer was warmly espoused by some but heatedly condemned by Franklin and Lavoisier. Divination, the pseudo-science of finding water, gold, or even criminals, by means of a bowing willow wand, came in for its share of criticism. There was great excitement over the doings of the Freemasons. Even the king was a member of a lodge; while Franklin, Lalande, Laplace and many other scientists of the day played leading rôles in this great secret order. The self-styled Count Cagliostro was setting up a super order of masonry with himself as the exalted head.

Madame Lavoisier presided over these famous dinners with grace and charm; the culinary preparations were made under her careful supervision and a generous pocketbook guaranteed the best of food. More than one guest has left his impression of his charming hostess. Said Arthur Young, English agricultural economist and traveller, "Madame Lavoisier, a lively, sensible, scientific lady had prepared a *déjeuné anglais* of tea and coffee, but her conversations on Mr. Kirwan's *Essay on Phlogiston,* which she is translating from the English, and on other subjects which a woman of understanding, who works with her husband in the laboratory, knows how to adorn, was the best repast." Franklin paid his generous tribute in a letter to Mme. Lavoisier: "I do not forget Paris and the nine years of happiness I enjoyed there in the sweet society of a people whose conversation is instructive, whose manners are highly pleasing, and who, above all nations in the world, have in the greatest perfection the art of making themselves beloved of strangers."

After dinner, the guests repaired to the laboratory of the Arsenal to watch their host perform some striking experiment in chemistry. Perhaps it was the preparation of inflammable air (hydrogen gas) and its violent explosion in ordinary air

which startled the guests; perhaps it was the demonstration of the levity of inflammable air in toy silk balloons; perhaps it was the preparation of vital air (oxygen) and the demonstration of its remarkable properties.

Said Arthur Young of Lavoisier's laboratory and apparatus: "That apartment, the operations of which have been rendered so interesting to the philosophical world, I had the pleasure of viewing. In the apparatus for aerial experiments, nothing makes so great a figure as the machine for burning inflammable and vital air to make, or deposit water; it is a splendid machine. . . . Mons. Lavoisier, when the structure of it was commended, said, *'Mais oui, monsieur, & même par un artiste français!'* with an accent of voice that admitted their general inferiority to ours. [English makers of scientific apparatus were generally regarded as superior to the French.] . . . I was glad to find this gentleman splendidly lodged, and with every appearance of a man of considerable fortune. This ever gives one pleasure: the employments of a state can never be in better hands than of men who thus apply the superfluity of their wealth."

Many thousand livres of Lavoisier's personal fortune went into the equipment of this superb laboratory. The apparatus for aerial experiments which Young so greatly admired cost Lavoisier fifty thousand livres. His precision balances made by Fortin cost six hundred livres each. Possessing none of the lavish and luxurious tastes of the times, Lavoisier's only extravagances were his beloved laboratory and his country estate at Fréchines. These extravagances he could easily justify; they were in the interests of science.

One of the most frequent guests at Lavoisier's abundant table was Pierre S. du Pont. Trained as a doctor, but practised in politics and economics, he had moved upward to a position of trust and importance under Turgot. For his fine work in helping to effect the Treaty of Paris ending the war between England and America he was granted a title by grateful Louis. The death of Madame du Pont in 1782 left him with two young sons to educate and place in an uncertain economic world.

Toward the younger of these sons, Eleuthère Irénée, Madame Lavoisier, herself childless, felt the fondness of a foster mother. He was often invited to dine at the Arsenal. "My son," wrote Pierre du Pont, "you are invited by Madame to dine at M. Lavoisier's with MM. Brogniard, father and son. Wear your velvet coat. Do not have your hair dressed. Do not spend an hour at your toilet. It need not be elaborate. I will stop by for you."

Pierre du Pont was anxious that his son, Irénée, make a good impression on M. and Mme. Lavoisier, for he hoped to place the boy, who already showed an aptitude for science, under the guidance of his good friend to learn the business of making powder.

In 1787, at the age of sixteen, Irénée du Pont took his humble position as an apprentice bookkeeper under Lavoisier's tutelage at the Arsenal. His older brother, Victor, wrote from New York: "I congratulate you on your admission to the gunpowder department. You, at least, have a definite profession while I am still without one." His father wrote, "Do all you can to please M. David and to gratify M. and Mme. Lavoisier. They are the best hope for your advancement and your fortune; the father and mother to whom I can leave you. Once they called you their son and if you are worthy of it they will always feel for you something of the tenderness that belongs to that relationship. My great affection for them has long been influenced by that which I have for you and by my wish to gain devoted friends for you. It will always help you to have a dignified position in that society whose prosperity is secure, and which has leisure for the cultivation of literature, the arts, and the sciences. It is a very great help to begin with such powerful friendships. . . . I was poor and no one was interested in me."[10]

The salary of twelve hundred livres was sufficient for the needs of the boy but the slowness of promotion chafed. Four years must be spent before there could be real advancement. To

[10] Du Pont, B. G., *The Life of Eleuthère Irénée du Pont from Contemporary Correspondence*, translated by B. G. du Pont. University of Delaware Press (privately printed), 1923. All quotations used in this book from letters between P. S. du Pont and E. I. du Pont and between E. I. du Pont and his wife are from the above source, volumes I and II.

complicate the financial problem of Irénée, he soon fell in love with the charming Mlle. Dalmas, who, like himself, had no wealth.

Kindly toward his motherless sons, Pierre du Pont nevertheless opposed this marriage on financial grounds. "Your position," he wrote, "in the department of powders promises advancement but it will be slow. They will start you with small places and may leave you in them. If M. de Lavoisier leaves the powder department for the treasury [which he later did] you will have no influence. You would have none in the event of his death. I have told you what Quesnay said when I married—'Behold, this fellow wants a bed and is not yet sure of a chair.' I had a salary of six thousand livres, the friendship of M. Turgot, Trudaine, M. de la Rochefoucauld, the elder Mirabeau, and Quesnay himself."

Lavoisier's policy in administering the manufacture of powder was one of impartiality and fairness to all, combined with strict economy; it was a policy which made him unpopular. He did not feel that he could promote young Irénée to the position the boy hoped for, but he did offer him advancement.

"My marriage," Irénée wrote to his father, "could in no way hurt my future if I could get the inspection of Alsace and I think I could if M. Lavoisier would ask for it." Instead of the inspection of Alsace, Irénée was transferred to the powder factory at Essonne. There he learned the art and practice of making fine gunpowder. It was a knowledge which would stand him in good stead in later years. Soon Irénée and Mlle. Dalmas were married; it was a union which proved most happy. Even Father du Pont was quickly reconciled to this marriage which brought him a charming and dutiful daughter who would comfort and care for him during trying days.

The fine training received under Lavoisier was not forgotten during the turbulent years to follow. With fortune gone and nothing to look forward to in Napoleonic France, Pierre du Pont emigrated in 1800 with his two sons and their families to distant America. Irénée, with a growing family to support, must find some occupation. A hunting trip furnished the sudden

answer to his problem.[11] American powder was of poor quality, judged by Lavoisier's standards. America needed powder mills! With his expert knowledge of powder-making, Irénée had soon established America's first great powder works on the banks of the Brandywine Creek in the state of Delaware. Pierre du Pont proposed the name, Eleutherian Mill, but Irénée preferred another name. He wrote to his father in 1803: "I have definitely decided on 'Lavoisier Mill' which is suitable and which shows my gratitude to the one whose kindness to me was the first cause of this enterprise. I hope that Madame Lavoisier will not disapprove of my giving their name to a large and well-equipped manufacture founded on the principles and discoveries of her husband and that would never have been started but for his kindness to me."

Unfortunately for America the name, Lavoisier Mill, was later dropped, leaving no symbol to connect the name of the great scientist with American chemical industry. It was Lavoisier's inspiration which led directly to the founding of the Du Pont powder works. And it was largely Lavoisier's great revolution in chemistry which made possible the conversion of a powder factory into a great modern chemical industry translating the findings of Lavoisier's science into the everyday needs and luxuries of a great democracy.

Another person for whom Antoine and Marie developed a warm admiration, was the great American philosopher, Benjamin Franklin, who arrived in Paris in 1777 to plead for the American cause. He was a welcomed and honored guest at the Arsenal.

Seeking to enlist not only the sympathy but also the material aid of France, Franklin was not slow to show his many-sided nature. With liberals he was more liberal than they; with diplomats he was more diplomatic than the best of them; with philosophers he was the wisest of the group; with ladies he was the courtliest of courtiers; and he could out-propagandize the

[11] The story that Eleuthère Irénée du Pont established his first powder mill as a result of a hunting trip in which he was forced to use inferior American powder was communicated to me in a letter by Mr. William S. Dutton. It is certain that the relationship of Du Pont with Lavoisier was the prime cause of his starting in this industry.

British ambassador, Stormont. At first a queer unwigged figure in Quaker garb provoking subdued mirth at the splendid court of Louis, he soon became the lion of all Paris. Painters vied for the honor of painting his homely countenance. To Madame Lavoisier he sat for his portrait, a portrait which she sent to him in later years and for which he thanked her graciously: "It is allowed by those who have seen it to have great merit as a picture in every respect; but what particularly endears it to me is the hand that drew it. Our English enemies, when they were in possession of this city [Philadelphia] and my house, made a prisoner of my portrait, and carried it off with them, leaving that of its companion, my wife, by itself, a kind of widow. You have replaced the husband, and the lady seems well pleased."

With his friends, Le Roy, Villiard, Lavoisier, and others, Franklin was often to be seen at meetings of the Academy, of which he was an honored foreign member. He listened attentively while Lavoisier read his famous memoir in 1778 but he leaves no record of his convictions on the subject of combustion. Inventor of an efficient stove still bearing his name and which depends for its efficiency on free access to oxygen, Franklin did not understand the part played by oxygen in the process of burning. Concerning Lavoisier's experiments with this new gas, Franklin wrote to Jan Ingenhousz: "He kindled a hollow charcoal, and blew into it a stream of dephlogisticated air. In this focus, which is said to be the hottest fire human art has yet been able to produce, he melted platina in a few minutes."

Rarely did the great Franklin have to share honors with others in any gathering. The dying Voltaire had, however, returned to Paris to feast for the last time on the plaudits of the masses. Voltaire and Franklin arrived at the open meeting of the Academy on April 29, 1778, at the same moment. It was the meeting at which Lavoisier was to give his famous memoir on combustion. There was thunderous applause as the two great idols entered the hall together. D'Alembert's memorial eulogies to De Jussieu and Duhamel were stopped. All business was set aside for the moment except that of cheering. Even this

was not enough: "Caressez à la française," rent the air. Nor would the Academy quiet down till the request had been satisfied. The bulky American and the venerable, cadaverous satirist must meet before the crowd to peck awkwardly at one another's cheeks. Then Voltaire took his honorary seat in the director's chair while Franklin took his place among the distinguished foreign members. The crowd was satisfied; D'Alembert continued his eulogy and Lavoisier presented his memoir.

Life at the Arsenal was indeed a busy one for Antoine and Marie. Ministers of state sought opinions on scientific subjects. Proper food for prisoners, sanitary conditions of hospitals and prisons, the trajectory of bullets, the distillation of salt water to obtain fresh water for ships at sea, the proper design for wheelchairs for invalids, detection of counterfeit currency, the use of hydrogen gas in balloons, the development of new standards of weights and measures, the development of better thermometers and barometers; all these questions and hundreds more engaged Lavoisier's attention.

He maintained a voluminous correspondence with foreign scientists, men from the provinces, ministers of the government. Every letter was carefully edited in his own hand. He was a member of many committees of investigation for the state or the Academy. Usually he acted as secretary-treasurer of the committee and was its virtual director. Appointed *pensionnaire académiste* in 1778, he was taking a vigorous and vital part in the affairs of the Academy. In 1785, he was its director; he succeeded Tillet as permanent treasurer in 1791. In the farm, he became, on the death of Baudin in 1779, a fullfledged farmer-general. He was one of the founders of the Society of Agriculture in 1785 and was appointed its director and secretary.

His days at the Arsenal were carefully and efficiently organized to provide time for his many activities. Rising each morning before six, he breakfasted, then repaired to the laboratory accompanied usually by Marie. There he worked on experi-

mental problems for three hours. Notes were carefully taken, usually in his own hand. While he was thus engaged, Marie was busy preparing accurate drawings of apparatus, translating articles from the English or digesting articles from the French. Or perhaps she would prepare a sketch of her husband at work on some problem. Two such drawings still in existence bear evidence of her artistic ability.

At nine o'clock came committee meetings of the farm, of the Academy, meetings with state officials, preparation of reports, inspections of powder plants, visitation of hospitals, checking of accounts.

At seven o'clock with an active day past, there was time once more to return to the laboratory, often this time with friends or guests. Every experiment was repeated before a group of colleagues before the results were presented to the Academy. Each guest was assigned a part in the experiment if he wished to participate. At ten, the evening was over, guests left, and it was time for six hours of rest.

One day in the week was set aside as a holiday—a queer sort of holiday—for it was a day spent entirely in the laboratory. "Some scientific friends, some young men proud to be admitted to the honor of assisting with the experiments were in the habit of assembling in the laboratory early in the morning. There they had luncheon and discussed and developed the theory which has immortalized the author. One should have seen him there to understand his clear reasoning, his great intellectual ability, his rare spirit. It was from his conversation that one could judge the greatness of his moral principles." Thus wrote a wife in loving memory of an idealized husband. On such days Laplace, Fourcroy, De Morveau, Berthollet, and the younger men, Gengembre, Hassenfratz, Adet, or Séquin were apt to be present. Occasionally others dropped in for luncheon and it was a merry group which stopped work long enough to partake of the bountiful buffet luncheon provided by the busy Marie.

Through the busy, active years of the heyday of France's dying splendor, Lavoisier was rising to wealth, importance,

and fame. Yes, his sumptuous table accommodated scientist, physiocrat, philosophe, noble of the robe, noble of finance and noble of the land. His wife and his friends idealized him; his achievements in science were startling. That was one side of the picture.

But there was another side to Lavoisier. The enthusiastic lad who rode gaily forth with Guettard to conquer the world of science was gone. Two men stood in his place, one Lavoisier the great scientist, the kindly man, the sincere liberal, the other, Lavoisier grown vain, ambitious, cold, unscrupulous, even irascible. This, at least, was the picture painted by a few contemporaries. Undoubtedly they were envious; nevertheless there was some truth in their painting. "M. Lavoisier," said one, "has no need to seek the philosopher's stone, he found it in his job." Another contemporary of the Paris Commune of 1789 wrote: "He spared nothing to discover a truth and counted neither labor nor money when it was a question of advancing a step. Doubtless it was this passion for research that made him so avaricious, indifferent to everything about him; it was perhaps this studiousness that made him so ill-tempered that his private life suffered greatly; he had no skill as a speaker, and he did not write well, but his ideas were so well organized, his reasoning so apt, his facts so precise, that one was sure to be convinced unless he closed both ears and eyes."

Were there no other evidence of the incorrectness of this statement than the contradictions in the statement itself, it could still be regarded as highly distorted. No man who did not write well or speak well could be as convincing as Lavoisier appeared to be according to this contemporary.

A tragic fate, as so often happens, mixes emotional highlighting with critical judgment of character so that it becomes well-nigh impossible to distinguish reality from fiction. Yet, if the warped picture painted by this contemporary is set off against the ideal one painted by a wife who presumably would have suffered most from "ill-temper" in "private life" we probably have a realistic picture of Lavoisier. It is true that critical judgment in science or elsewhere is often accompanied by a

dispassionate attitude which is readily mistaken for either coldness or indifference—but this coldness does not necessarily extend beyond those things toward which critical judgment is exercised—it need not pervade private or home life, or friendship. There is every evidence that it did not pervade Lavoisier's home life. The dogged persistence with which Lavoisier fought to force his new theory down the throat of science, his continued attacks on old dogma, could easily be regarded as intolerance and arrogance. They were certainly not calculated to win friends, even though they might win admirers.

Even nationalism warps the picture. To many an Englishman, Lavoisier was merely a pirater of scientific ideas, a wealthy farmer dabbling in science and stealing the gems of Priestley and others to adorn his own crown. Some Germans were not adverse to such a view either. Certainly his contest with Priestley injured his reputation in science and left Priestley's unscathed. There is a simple answer to this; Lavoisier had to use Priestley because he was building a comprehensive theory and Priestley's discovery was an integral part of it; Priestley, on the other hand, had no need to use Lavoisier because he was building nothing, merely discovering facts. That applies as well to all those from whom Lavoisier got ideas. He needed them because he was building; they had no need of him because they were not building. Even his social position in France was anomalous. What was a farmer of the taxes doing in the ranks of the physiocrats; how could one who claimed to believe in the ideals of the philosophes reconcile such belief with gain of wealth in an organization which resisted the financial reforms of Turgot and all others, which was a very cornerstone of ancient privilege? Was Lavoisier a reformer at heart or did he merely wear the colors of a reformer on his sleeve because it was the vogue? Did he invite philosophes and physiocrats to his table to disarm the common enmity felt toward the farmers of the taxes? Did he ever regret his connection with the farm?

There is certainly no evidence that he was insincere in his social and political beliefs either now or later. He held to them

throughout his life—even when it became unpopular and dangerous to do so. But they were not the views of an ardent reformer of the Robespierre or even of the Condorcet type. He was a practical realist believing in reform granted from the top, not seething upward from the bottom, believing that the masses, for their own good, must be governed by men from the upper walks of life.

While he was not the most ardent of physiocrats, neither was he the most reactionary of the farmers. Turgot trusted his good judgment. There is a strange silence regarding his activity on the administrative committee of the farm, if indeed, he actually ever served on that committee. He was nominated by D'Ormesson in 1783 who wrote to him "You have known my feelings toward you for a long time. I am taking advantage of this occasion to give you a proof of this by informing the *ferme générale* of my intention to have you made a member of the Committee of Administration. I believe that the *ferme* will be more than willing to accede to my wishes because I have been informed of the esteem and respect which you enjoy there." Does the strange silence concerning Lavoisier's work on this committee arise because he, favoring reform in the farm, found himself in the minority? Did he soon resign or did he never serve? A later statement leads to the conclusion that he had little or nothing to do with this work. He was a great committeeman and very seldom, if ever, was he a silent member of any committee. Is it likely that a man of ill-temper or indifference would have sought or accepted the many committee posts held by Lavoisier?

From these several lines of evidence, a realistic portrait of Lavoisier can be synthesized. He stood alone, moving with, but not in, the tides that carried France to Revolution. He was neither a zealot for reform nor an adherent of the status quo. He was not indifferent and ill-tempered but critical and efficient. He was certainly not sentimental or soft-hearted but he was ever ready to support and promote ability in others with pocketbook and influence. It is true that he "spared nothing to discover a truth" but this passion did not make him "indifferent to everything about him." He was not off in another world

dreaming his scientific ideas; he lived realistically in the world about him, applying efficiency to his science, his business life, his social and political thinking. He lived alone in science, between right and left in political thought, and well above the middle stratum of society.

Life in Paris. Charlatanism

THE boisterous and banal 1780's were at their height. Paris, capital of noisy mirth, laughed with, and at, itself. Nor did it bother to reckon the cost. Dashing madly hither and yon, from Versailles to Paris, from the Tuileries to the Champ-de-Mars, from the Palais Royal to the Opéra in search of pleasure, it was stripping itself of the last vestiges of virtue, chastity, and nobility in its "Dance of Death."

Freedom of thought brought in its train freedom of expression. "Sire," said the old rake, Duc de Richelieu, "under Louis XIV no one dared to utter a word; under Louis XV they whispered; under your Majesty they talk aloud." Not long hence they would be shouting, "Revolt!"

Pagan Paris was the Mecca of every adventurer in Europe; it drew to its gilded bosom every quack, sorcerer, alchemist, cultist, propagandist and charlatan who could find the means to travel. There would be found devotees for any cult, clients for any form of sorcery, patients for every patent remedy, purchasers for alchemistic gold and dupes for any new and startling hoax. There were invisible inks for the intriguers, Spanish perfumes for the seducers, spiritualistic séances for the believers, magnetic tubs for the mentally ill, mixtures of magic chalk and water for the incurables, elixirs of life for the eternally young, gold from base metals for the credulous, diamonds from the glowing crucible for the beautiful.

There was another Paris; a sodden Paris of the hopeless poor, a Paris which looked through half-closed eyes at its other part, then slunk back into its cellars and garrets to await the day.

There was also a Paris which saw with open eyes all that lay before it—saw the squalor and the misery, the glamor and the hypocrisy, saw and strove with all its might to bring the ends closer together. This was the Paris to which Antoine and Marie Lavoisier belonged. To the moral looseness of the day they were not parties; against the quackery of the day they set their faces. Only the opera claimed their constant support. Loving music as musicians themselves, they held permanent reservations for the opera. Even this reasonable luxury would become the object of cold scrutiny in later years.

In idle society, Lavoisier was not particularly popular. He was no wit, cared little for obscene jokes or idle tales, could muster little interest in popular scandal. He had become more reserved with age and responsibility. His keen insight into the troubled economics of the times, his position as a liberal and a physiocrat, his unbending opposition to fraud of all forms placed him often on the unpopular side of current questions. His stern judgments and sharp pen added little to his popularity among the élite. An unfortunate incident served to heighten his unpopularity among both the rich and the poor. It was an incident coming from his association with the farm.

It was an easy matter to slip produce into Paris without passing it through the tax gates. Fully a fifth of the produce came in through devious byways. Merchants complained bitterly of competitors who, handling this contraband, could undersell them. The nation was losing tax money, the farmers, profits.

A wall around the city to prevent this smuggling was proposed by the farm. For two years the proposal lay dormant, then Calonne, the minister, decided in favor of it. Instead of the simple wall proposed, however, Le Doux, the contractor, built a luxurious ornamented stone barricade with elaborate gates and fancy trimmings, spending on the job some thirty million livres. Paris was aghast! Mercier called it a new fortress. De Nivernais, Marshal of France, declared, "I am of the opinion that the author should be hanged. Happily for M. Lavoisier this advice has not yet been followed." All Paris, rich and poor, complained, stormed and denounced. The wall

cut off the pure air, kept in the bad, made the air heavier, harder to breathe; as a result there was more sickness. So argued unscientific Paris.

Soon, the wits of Paris had coined the popular refrain:

> "Le mur murant Paris
> Rend Paris murmurant."

Indeed, all Paris more than murmured at the walls walling Paris. The farm likewise came in for its share of unpopularity in verse. Said the wags:

> "Pour augmenter son numéraire
> Et raccourcir notre horizon
> La Ferme a jugé nécessaire
> De nous mettre tous en prison."

The farm had put Paris in prison. Who was the originator of this prison wall? "Lavoisier," said an anonymous pamphlet. "Everybody thanks Lavoisier as the patriot to whom we owe this ingenious imprisonment of the capital. The farm may raise a statue to him but the Academy blushes for his membership in the farm."

Since he made no reply to the accusation, Lavoisier stood condemned. Nor was he, apparently, greatly concerned over the attack. He saw only the opportunity of eliminating the evil of smuggling. The enterprise succeeded but some would never forget Lavoisier's part in it. There was one, in particular, who would never forget or forgive. It was Jean Paul Marat, popular doctor of medicine and scientist of sorts, who was seeking to crown his scientific achievements with membership in the Academy of Science.

In England, Marat's literary and philosophical essays had met with adverse criticisms. These "persecutions" led the Swiss doctor to depart for better lands. The Hague, Utrecht, and Amsterdam saw him for a short time, but he could not long resist the attraction of Paris. In the capital, he became physician to the bodyguard of the king's younger brother, the Comte d'Artois. Along with this work came a sizable fashionable practice. His miraculous "cure" of the Marquise de Laubes-

pine, who supposedly suffered from incurable tuberculosis, was enough to bring fame to the "doctor of the incurables" and to his patent remedy *eau-factice-antipulmonique.* Soon, all the wealthy were drinking of his expensive chalk and water mixture.

Marat's real ambition, however, soared higher than mere success in magic medicine. He would emulate and surpass Newton in the field of science. With Franklin in Paris, electricity was all the rage; Marat took up electricity. Franklin was invited to witness his experiments but was not greatly impressed. Nevertheless, Marat might use Franklin to promote his cause before the Academy. In English, he wrote him an awkward, appealing letter: "Was it not so material a point to the author that a candid judgment should be passed upon his work, he would trust to time alone. But he is certain that many Academical gentlemen do not look with pleasure upon his discoveries (and he undoubtedly referred to Lavoisier) and will do their utmost to prejudice the whole body. Let the cabal be ever so warm, it certainly will be silenced by the sanction of such a man as Doctor Franklin, and how far a judgment passed by himself and the Royal Academy can influence public opinion is well known."

The Academy failed to pass favorable judgment on the work and Franklin failed to answer the appeal. Marat did not give up, however. His next memoir was on *Medical Electricity,* flavored by the popular influence of Mesmer and his magnetism. Following that, he translated Newton's *Optics* and wrote an essay on *Discoveries in Light* which carried off a prize offered by the Rouen Academy. A few academicians were beginning to look with some favor on the versatile doctor. Sage, Lamarck, Cousin, Condorcet and Le Roy favored his election.

All might have gone well with Doctor Marat's candidacy, but he chose to enter the field of fire for his next memoir, entitled *Physical Researches on Fire.* He claimed that the flame of a candle in a closed container went out because the hot air pressed on it, that fire was an igneous fluid. Then, somehow, there appeared in the *Journal de Paris* a notice that

the Academy of Science had placed its stamp of approval on this work.

The memoir drew fire in plenty—from the tongue and pen of Lavoisier, master of the true theory of combustion. Marat had chosen the wrong subject to write about in his nebulous manner. Lavoisier lost no time in denouncing the idle speculations of Marat and in condemning the subterfuge employed to command attention. The Academy had not placed its stamp of approval on the memoir—nor would it. Marat's speculations were nothing more than the old theory of phlogiston disguised in newer garb.

Against the opposition of the influential Lavoisier, Marat stood no chance of election. Had Lavoisier known what the eventual outcome of his attack on Marat would be, he might well have swallowed his convictions. Marat, academician, would have been a different Marat in revolution. With Lavoisier, Condorcet, and Bailly, he might have taken his stand as a liberal leader of a popular cause, not as a demagogue. But Marat, defeated in his great ambition, became the archenemy of the philosophers.

The rebuff by the French Academy of Science was followed by an abortive attempt to gain the ear of the scientifically-minded Frederick of Prussia; failing that, to become the loyal Spaniard and Catholic De Mara, and thus to secure appointment as director of the Madrid Academy. But the doors of science were closed. Fate had cast Marat for a different rôle, a rôle which must have surprised even Marat himself.

Again taking the unpopular side of the question, and, incidentally, gaining little favor with the ardent Marquis de La Fayette for his stand, Lavoisier took up the fight against the all-popular Mesmer and his animal magnetism which was sweeping all Paris before it.

Doctor Mesmer had dropped into Paris by way of Berlin from Vienna in 1781. In Berlin, it was the mystic influence of the planets on the lives of men which Mesmer expounded. In Paris he changed his form of magic. It became the mystical curing influence of animal magnetism on the human body and soul. Everyone knew that a lodestone had magnetism. Human

beings, too, said Mesmer, possessed magnetism. Properly attuned to mineral magnetism, illnesses might be drawn from the body.

The imposing establishment of Mesmer soon became the rendezvous for all the fashionable set. La Fayette became the chief devotee. "What will Washington say," asked the king of the marquis, "when he learns that you have become the first apothecary's apprentice to Mesmer?"

Though the Royal Society of London termed Mesmer "mad," though the Academies of Berlin and Paris refused to endorse his magnetism, Mesmer prospered. When he cured a young girl of a fatal malady after three months of treatment, his fame was assured. The great Doctor Deslon, from arch-enemy, became an ardent disciple. Nobility entered his doors on canes, crutches, and stretchers, and left "without" support. Mesmer's magnetism was greater fun than St. Martin's spiritualism.

An evening at Mesmer's was a never-to-be-forgotten experience. Ladies and lords of high degree, often masked to conceal their identity, came in their carriages. Courteous attendants led the clients through the antechamber to the dimly lighted hall. There, in the center, stood the massive kettle with its sulfurous brew dimly glowing. The patron took his seat in the circle; a chain leading from the magic kettle was fastened to his ankle to serve as a conductor for the "magnetism." By holding hands around the circle, the circuit was closed and the magnetism pervaded every subject in the room. To the strains of soft music, the subtle magnetic fluid did its curing work. Patients closed their eyes; some writhed in ecstasy, others smiled in joy; all felt their pains and troubles disappear into the magic kettle. There were sighs, cries of delight, groans of fulfillment. Then came Mesmer in a robe of velvet as from nowhere. Each patient was touched with the magic wand. The séance was over; it was the turn of the cashier to collect the fee. Servants helped the slightly confused and dazed patients to their carriages once more.

Throngs of the curious watched their more fortunate brethren come and go. To entrench himself more firmly in good will,

Mesmer "magnetized" a tree outside his mansion. Here, the poor and the curious might come and touch the tree without paying a sou to the generous Mesmer. Many a poor soul caressed the tree and went away cured, blessing Mesmer—till the pains returned again.

Though the government offered to buy his secret, Mesmer was offended at the paltry sum offered and refused to sell, refused to sell even to a group wishing to float a stock company. Mesmer was wise. Entrenched in good will, he was riding the crest of popularity.

But crests become breakers. Marie Antoinette was displeased with Mesmer. He was drawing the crowds even from her court. Louis, of course, was displeased, too, though he cared little about the matter. He suggested an investigation of Mesmer through the Academy.

The Academy was eager for the opportunity. Popular Ben Franklin, authority on electricity, was appointed to the investigating committee; Lavoisier, eager to serve the cause of science against fraud, became secretary of the committee and its virtual director; while Bailly became chairman, and Le Roy, together with Dr. Guillotin, made up the balance of the committee.

Mesmer wisely declined to demonstrate before the committee and found it convenient to be absent. Deslon, less shrewd than his teacher, agreed to perform. To the home of Franklin, suffering with the gout in Passy, Deslon brought seven patients. Each was blindfolded and informed that certain trees in the garden had been magnetized. "At the first [tree] he shuddered; at the second, he foamed at the mouth; at the third, he gave a death rattle; and at the fourth, he fell down electrocuted." Of course, none of the trees had been (or could be) electrified.

The committee was satisfied that the whole business of animal magnetism was a hoax. More than that, it was closely tied up with eroticism. The report was devastating. Hurriedly, Mesmer decamped from Paris in spite of the protests of La Fayette that the committee was unfair. Wrote Lavoisier in his objective manner: "The art [of curing] consists in evaluating the probabilities and estimating whether they are complete enough to provide suitable proof. This is more difficult than

we think and demands a sagacity above human intellect. Upon these difficulties in evaluation is founded the great success of charlatans, sorcerers, alchemists, magicians, enchanters and all those in whom a credulous public puts faith. . . . The multitude regard a cure as a proof of the efficacy of the remedy. But there is no proof unless a great many facts point to it."

Here is Lavoisier's scientific judgment displayed at its sternest, admitting possibilities, but demanding clear objective proof before science can accept the fact. He sought to determine, not the curative properties of magnetism, but whether there was such a thing as magnetism. He brushes aside that which cannot be evidenced, as so much chaff, and limits science rigidly to that which can be proved. In doing so, he closes the door of science to phenomena not interpretable in an exact sense to the senses; he separates exact science from philosophical thought and ushers in an era in which empirical, fact-gathering science parts company with philosophy. He was doing what Bacon had done two centuries earlier, but doing it far more exactly. It was a necessary step for science to take, for until science could thus objectify itself, it must remain entangled in the webs of mysticism, magic, and mental gymnastics. It was a step, however, which robbed science of the colorful fruits of philosophy. For more than a century science must go its own way, gathering facts, establishing hypotheses, supporting theories and building the great framework around its endeavors.

To Lavoisier there could be no grain of truth in Mesmer's magic, yet Mesmer's idea in its more modern form has branched out into clairvoyance, mental telepathy and hypnotism, each still filled with fraud difficult to detect, but each yielding evidences of truth, beyond the fraud and sham, too significant to ignore. Science, which for a century denied even the possibility of such phenomena, has begun at last to evaluate these perceptions more accurately. Mesmer may have been a fraud, but Lavoisier's objective mind was not capable of seeing through the trappings the significance of the power of suggestion.

Most infamous of all the charlatans of the day was not Mesmer, but one Joseph Balsamo, the self-styled Count Cagliostro. His fraud-strewn path did not bring him into direct conflict

with Lavoisier, but his magic was characteristic of the type of pseudo-science of the day against which Lavoisier fought with clear objectivity.

Cagliostro had travelled much in his magnificent coach—and sometimes hurriedly, as his schemes threatened to catch up with him. Germany, England, and even the Orient, so he claimed, had witnessed his magic. But it was in Paris that he finally sought the alchemist's haven. In his canary-colored waistcoats, he ruled over a mansion of magic.

Did his clients want gold, Cagliostro made it for them before their very eyes; did they want diamonds, the gems sparkled in the glowing crucible; did they want perfumes to intoxicate and subjugate, the mystic fluids poured forth from vials; did they want subtle poisons, they got them, poisons which left no record of their deadly work; did they want the elixir of life, Cagliostro had it for them, the elixir which would make old men young again and young men young forever. Was not Cagliostro himself veritable proof of the potency of his own elixir? In his youth, he claimed, he had been a guest at the marriage feast of Cana; he had even talked with Christ upon the Cross. Nor was his any mere reincarnation from a former life. Through eighteen centuries, he had lived continuously, always young and vigorous. Now, at last, he was beginning to age. That was his story.

Lavoisier was not concerned over Cagliostro's magic, for it was pure magic without a hint of scientific basis. The magician wrote no memoirs claiming scientific merit for his works, no books on magic which would subject him to attack by scientists; he avoided scientific circles and kept his secrets to himself. It is not surprising, therefore, that he avoided conflict with Lavoisier.

Another form of fascinating magic of the day, a magic which Cagliostro avoided because it laid claim to scientific merit, a magic which, like goldmaking, has lingered on into modern times, was that of divination.

With a forked willow wand properly manipulated in the hands of a psychically attuned person, water, precious minerals, even buried treasure could be located far beneath the sur-

face of the ground. The operator walked silently over the ground, the forked wand extended before him, grasped firmly by the prongs. Above the buried treasure, the wand began to dip. Valiantly the operator struggled against the dipping pointer. The more he struggled, the more the wand drooped. The answer was given. "Dig here!" There beneath layers of earth and rock would be found water, minerals, or buried treasure.

Some diviners had carried the art far beyond such simple tricks. Like a bloodhound on scent of a trail, the magic wand might lead its operator in pursuit of criminals. There was the famous case of the psychic peasant, Aymar, who, in 1692, followed for many months the trail of the murderers of a Lyons vintner and his wife. Down the Rhone, back to Lyons, on to Languedoc and finally, to the gates of a prison in Beaucaire, the magic wand led Aymar. Before a poor hunchback arrested the previous day for petty thievery, the wand dipped knowingly and sharply. Back along the devious trail were those who had seen the hunchback pass in his flight from the murder. The evidence was in—no need for further proof. Torture and credulous faith in magic sufficed to wring a halting confession from the shivering wretch. He had stood guard while two others committed the crime. Had he? Probably not. But the gallows exacted retribution. Aymar was a hero; his fame grew like a bursting sun. Soon he had traced the true parents of a foundling child. All France sought Aymar's services.

When the Duc d'Ayen found an expert water diviner near his estates, he wrote to Macquer concerning a scientific test. Macquer called in Lavoisier, expert in the study of water supplies. Lavoisier was eager to make the test. A spot near Bourget surrounded, except for a narrow neck, by a stream of water, was chosen for the experiment. Blindfolded, and at night, the diviner was brought to the spot. Cautiously, he stepped forward—no water in that direction, no water in this direction; here, on the other side, one must dig to locate water. Alas for the diviner, there was water in all directions.

Lavoisier wrote to the Duc d'Ayen: "The talent of guessing the location of water is just about as marvellous as one wants

to believe. There is water everywhere—it is rare to dig a well without finding it at least ninety per cent of the time. The spontaneous movements of the wand depend upon the movements of the bearer and many persons of good faith are thus deceived." Lavoisier's explanation of the movement of the wand was that which science has given ever since to this phenomenon, nor was Lavoisier the first to give it.

More mysterious even than the divining rod was the hydroscopic lad, Jacques Pargne, whose eyes could pierce through soil and rock to see buried treasures far beneath the surface of the ground. When the credulous *Gazette* printed this story and others like it in good faith, Lavoisier was moved to a sharp rebuke. "The philosophers," he wrote in the *Journal of Physics,* "complain bitterly when those who should be above such vulgar superstitions drag forth old absurdities long since proved false. . . . Must philosophy lose all the ground it has gained?"

Such was the state of science that even the learned Academy half believed these stories. When an investigation of Pargne was suggested, Lavoisier retorted, "Such action will give undue credence to the very idea and bring dishonor to the Academy." The case of Pargne was not investigated but the facts soon proved that Lavoisier was right. The boy turned out to be just another clever rascal.

Paris enjoyed fêtes of all kinds in these gay times. Displays of fireworks brought forth huge crowds to line the banks of the river, throng the Champs-de-Mars, or fill the gardens of the Tuileries. Now Paris was to have a new thrill calculated to stir its imagination to the very core. The Montgolfier brothers, at the request of the Academy, were coming to Paris to demonstrate their new device, a great linen bag lined with paper and filled with hot air from a straw-burner, which would rise into the air and float like a planet in free space. It was Europe's first balloon. Man's ancient dream of riding through the air was about to become a reality.

So eager was Paris for the spectacle, it could not wait for the Montgolfier's hot-air balloon. Charles, eminent physicist and physician, visioned a balloon filled not with hot air, which

quickly cooled. but with the new gas, inflammable air, or hydrogen, lightest of all the gases. A balloon was quickly built of varnished silk; and before the eyes of the astonished multitude assembled at the Champ-de-Mars, the first hydrogen-filled balloon rose majestically into the air on August 27, 1783. Even a pouring rain failed to hold the balloon to earth—or dampen the enthusiasm of the crowd.

Then came the Montgolfier brothers with their hot-air bag to perform before royalty in the garden of Versailles. For the first time in history, a balloon carried living passengers—a sheep, a duck, and a cock. If animals and birds could weather the flight, why not man? On October 15, 1783, Pilâtre de Rozier bravely seated himself in a wicker basket suspended from a Montgolfier balloon. The rope was paid out and Pilâtre, bowing to the applause of the multitude, rose into the air to the limit of the anchoring rope. It could be done! Man could be lifted into the air beneath a bag of gas! The next step was quickly taken; Pilâtre de Rozier and the Marquis d'Arlandes seated themselves in a wicker basket; the huge bag was released and sailed off into space to come down unharmed several miles away.

Trips in hot-air balloons, however, were of short duration. The air cooled and the balloon descended—sometimes abruptly. In December came the first aerial journey in a hydrogen balloon; Charles and Robert were the balloonists. For two hours they soared, covering some twenty-seven miles and rising two miles into the air.

Ballooning was a huge success! Henceforth, no pageant was complete without its balloon ascension. Gaily caparisoned balloons sailing lazily over Paris became a sight too common to evoke surprise from the pedestrians below. Excitement seekers found the new adventure of riding the air surprisingly dull after the first trip.

Soon the balloon came in for a new use—to advertise and to spread propaganda. Hormont suggested to Lavoisier that mesmerism might well be ridiculed from the air. A balloon of goldbeater's skin supporting a man with a Mesmer bucket on his head would suffice. Lavoisier referred the matter to Bailly.

"Since," he wrote, "I am coming over to Breteuil's view that the way to discredit mesmerism is to ridicule it, I think this trick might do it. I request that you talk with him about the matter." Whether this bit of propaganda was ever used is not known, but in all probability, it is the first suggestion of such use.

The significance of this novel toy in warfare and national defense prompted the government to confide its perfection to a committee composed of academicians. Lavoisier was in his usual place—as secretary of the committee. There were numerous problems to be considered, problems which Lavoisier outlined at a meeting held in the Paris mansion of the Duc de la Rochefoucauld. How could diffusion of the gas through the fabric be prevented; what material was the least porous and most flexible; what ballast could be used; could the unwieldy bag be propelled in some manner (great oars were often used to row the bag up, down, and through the air); how could the hydrogen gas best be prepared; could balloons be navigated or sailed against the wind?

Lavoisier himself was studying suitable economic means of producing hydrogen gas in quantity. The king, at first opposed to balloons, soon became an ardent supporter of all that pertained to ballooning. He wrote to Lavoisier, "Your latest experiments, sir, attract my admiration. . . . You have increased the sphere of useful knowledge. Your experiments on inflammable air prove how well you are occupied with that admirable science which makes new progress every day. The queen and others who wish to witness your experiments will unite in my apartments at 7:00 p.m. tomorrow. Will you kindly give us the pleasure of bringing your experiments on inflammable air." No doubt Lavoisier entertained and enlightened this royal audience with his experiments on hydrogen, but history reveals no details of the meeting.

Appointed director of the Academy of Science in 1785, Lavoisier immediately applied his zeal to the unpopular task of reorganizing that ancient body. He proposed abolishing the degrading rank of assistant in favor of admitting newcomers to the higher rank of associate; he proposed the granting of voting

privileges to all members. Finally, he proposed that all officers of the Academy be elected by vote of members and not appointed by the king. In spite of opposition, these reforms were carried through.

The director of the Academy was its working leader, the president, its honorary head. To Lavoisier, then, fell the many routine duties. He must plan the order of procedure, supervise programs for meetings, pass on papers to be presented, look to the publication of the transactions (and these were always several years in arrears), supervise the activities of the many committees, preside with the president at the formal meetings, stir up the lax secretary, Condorcet, to his duty of presenting eulogies of deceased members before the member was completely forgotten, and present newly elected members to the king, queen, and dauphin.

This last, in itself, was no minor ceremony. The gentleman of the king's chamber and the lady-in-waiting to the queen must be properly notified and the presentation arranged for. At eleven o'clock came the formal presentation to His Majesty; at one, the queen received the new academicians. There still remained the dauphin, the Comte d'Artois and the ministers to be seen. Among those presented by Lavoisier were Lagrange, recently returned from Berlin, the Abbé Tessier, Charles, Broussent, and Fourcroy.

Always generous and charitable, Lavoisier gave willingly of his ample funds—but never sentimentally or spectacularly. Though he kept careful account of his own expenditures and his loans, he leaves no record of his many gifts. These can only be surmised from the few evidences available.

When the great friend of his youth, Jean Guettard, was forced to retire from his position as curator of the museum of the Duc d'Orléans, Lavoisier purchased many of his books for a liberal sum, and on the death of the old master, took charge of his affairs. When Baudon died in 1779, Lavoisier purchased his share of the lease in the farm while still reserving to Mme. Baudon a third of the profits—a generous act quite unnecessary from a legal standpoint. He was largely responsible for placing the poor but brilliant young Gengembre in the

chair of physics at the museum. He helped Adet, who was to become the first minister from France to the United States, to start his *Annals de Chimie.* He recommended Fourcroy to the Minister of Finance, assisted De Morveau to secure the position of procurator of finance, and loaned generous sums to start Pierre du Pont in the publishing business.

When the disastrous summer of 1788 ruined harvests, he opened his purse to the city fathers of Blois and Romorantin to purchase wheat for the starving. These were loans without interest, "not an investment of funds." Both cities rewarded him with honorary citizenship, honors which he treasured far more than his patent of nobility. Toward his adopted city of Blois, he felt a kinship equal to his love of Villers-Cotterets. A portion of these loans was never repaid.

During the days when he was most actively building his new foundations of chemistry, carrying his burden of administrative work in the farm, the powder commission, the Academy, and the Society of Agriculture, he found time to submit more than fifty reports on many diverse subjects, from the adulteration of cider to the natural history of Corsica. He was a co-author of many more, and edited numerous reports in which his name did not appear. Most of this work was done at the request of various ministers and for the State. Lavoisier was, indeed, a striking refutation of the charge that men of science are impractical visionaries; his active mind coordinated scientific genius, business efficiency, political vision, and public benefaction in a perfect harmony of tone. There have been greater scientists, greater economists, greater organizers, in the history of mankind, but seldom has the world seen a finer example of synthesis in one human mind. Had science failed to claim Lavoisier for its own, business, economics or political science would have done so.

Serving his less fortunate fellow man in a multitude of ways, intent upon bringing better life to the masses, Lavoisier served on a committee appointed by Necker to study the deplorable conditions of Parisian prisons and hospitals. With Tenon, Duhamel and others, he visited the hoary old hospital, Hôtel Dieu, and the grim Conciergerie.

The shifting centuries had brought little change in the oldest of Parisian hospitals. Only the poverty-stricken went there and even they shuddered as they entered, shielding their noses from the stench, their eyes from the view. In massive old wooden beds, five or six feet across, lay patients, five to a bed and of mixed sex and age. To conserve space, the feet of one patient rested against the head of the next. In the same bed, lay those with consumptive cough, burning fever, scabbed skin, broken limb, and contagious disease. A century must yet pass before another great Frenchman, Louis Pasteur, would open the eyes of the world to the meaning of bacteria and contagion. A century must pass before Pasteur would do for bacteriology what Lavoisier was now doing for chemistry.

Said Tenon in the committee's report: "Scabies is almost general. It is perpetual. The surgeons and the nuns contract it; the discharged patients carry it back to their families and the Hôtel Dieu is the hotbed from which it is spread all over Paris." He denounced the practice of rinsing all dishes in the same tepid water; he demanded that the obstetrical department be moved to more sanitary quarters and that efforts be made to stamp out the constantly recurring puerperal fever which claimed so many mothers.

The scathing report brought in its wake hard feelings, but with these, also came reform. New hospitals were planned, old ones were changed; both prisons and hospitals were systematically cleaned and, at Lavoisier's suggestion, fumigated. Soon there was less complaint about scabies.

"The true end of a government," wrote Lavoisier, "should be to increase the sum of enjoyment, happiness and well-being of all its citizens. . . . The unfortunate peasant groans in his hut; he has neither representative nor defender; his interests are counted of no value in the administration of the kingdom. . . . He pays a head tax, works out a highway tax in the corvée, pays a feudal tithe and an ecclesiastical tithe, produce tax, salt tax, tobacco tax, must permit right of search, sees his lands turned into swamps by dams. If commerce is more protected than agriculture, it is because merchants as a class of citizens

are awakened, know how to talk and write, live in cities and make their voices heard."

Thus did Lavoisier rise to the defense of the inarticulate peasantry of France. He was doing far more; like many others of his class he was setting an example in efficient, modern agriculture. In 1778, he purchased the estate known as Fréchines in the Département de Loir-et-Cher, not far from his adopted cities of Blois and Romorantin. Some six hundred thousand livres went into the purchase of this estate and one hundred twenty thousand more into the development of scientific agriculture. Fréchines was not a summer home, but a busy working example of a model farm. Planting and harvesting time usually found the proprietors present to witness the results of agricultural experiments.

With carefully controlled methods, Lavoisier began his experiments in agriculture. Three of the poorest plots of ground were selected and carefully drained. Sowings and yields were weighed, fertilizer measured. Rams, imported from Spain, greatly improved the quality of both sheep and wool. By selecting better cows for breeding, the quantity of milk was increased. Rotation of crops, intensive agriculture, and careful fertilization brought their rewards. The yield of wheat was doubled, new crops were enthusiastically tried. The peasants of Blésois found their lot greatly improved.

"Such changes," said Lavoisier, "come about slowly . . . ; peasants weighted down by their heavy taxes are powerless to change their methods. . . . At the end of the year they have nothing left and are thankful for a bare existence. It is necessary for the proprietor to finance experimental work. Such investment does not present the speculative brilliance of stock gambling, neither are there risks of great loss. . . . An intelligent proprietor cannot increase the value of his lands without spreading ease and happiness around him. . . ."

Around Blois, there linger on among the people grateful memories, not of a critical scientist, but of a generous leader who came among them to lighten their labors, increase their yields, loan them money without interest in time of crop failure, and fight for their rights in the provincial assembly of Orléans.

Lavoisier, the idealized country squire, can be seen in the word picture painted by an admiring wife, a picture strangely like that painted of Voltaire, the sage of Ferney: "There, one saw him with the people, acting as a magistrate, settling disputes, returning an erring son to his parents . . . visiting the sick and leaving gifts of money, encouraging the peasants, advising patience and hope, founding a school where none had existed before, paying and boarding its instructor, selling provisions to peasants below cost so as to preserve their pride and sturdy independence and prevent them from becoming objects of charity."

A strange contradiction of qualities was this man characterized by friends as kindly, generous, sympathetic, helpful, and by his enemies as shrewd, calculating, ambitious, cold, and unscrupulous. In the end, friend and enemy must agree on one point: he was the scientific organizer of his century. None could rob him of that claim to immortal glory.

Cavendish Discovers the Composition of Water

LORD HENRY CAVENDISH had just discovered an astonishing fact—at least it would seem astonishing to a scientific world still bound to the four mythical elements of the Greeks; it would seem surprising even to the astute Lavoisier. But to the machine-like mind of the dispassionate Cavendish, it was just one more scientific truth. Furthermore, there were things he still could not understand about this new discovery. So, for three more years, from 1781 to 1784, Cavendish worked on the puzzling evidence wholly unaware—and quite unconcerned—that a major scientific controversy would be the result of his delay. Not till January 1784 was Cavendish ready to tell the world that water, regarded since the time of Aristotle as an element, was, in fact, not an element at all. It was a compound!

In the intervening trio of years, two other men, at least, reached somewhat similar conclusions. They were James Watt, promoter of the steam engine, and Antoine Lavoisier. Around these three great figures and the question of who first discovered the composition of water would arise a controversy lasting more than a century, a controversy in which bitter words would be hurled first at one, then at another of the famous contenders.

History has finally agreed—as well as history can agree—on the respective rôles to be assigned to each in this famous war over water. Even today, however, all the evidence has not been exhaustively sifted. To follow the train of men's thoughts in the development of a conclusion is manifestly impossible when such thoughts were never reduced to writing. Cavendish, unlike

the voluble Priestley, was a man of few words, either written or spoken. He fled from fame and hesitated to publish results. If right, results brought more embarrassing fame; if wrong, increased morbid shyness. Watt, too, was a shy man, favored by circumstances to become a great inventor. As a theorist, Lavoisier faced one serious defect in his bold new oxygen theory of combustion. Till he could give a satisfactory answer to the phlogistonists on this score, he could expect little support from the scientific world. It was inflammable air first noted by Hales then rediscovered by Cavendish in 1766 which was causing the trouble.

Cavendish obtained this gas by treating certain metals with acids. Metals, it was supposed, contained phlogiston; this new gas came from the metals; it burned vigorously. It was, reasoned Cavendish logically, phlogiston itself. There was still further evidence to support such a supposition. When the water was evaporated from the remaining solution and the solid product was heated strongly, there remained a calx of the metal identical with that obtained by Lavoisier when the metal was heated in air. Evidence enough that the phlogiston had left the metal, leaving the calx behind! Cavendish had, so he thought, verified the truth of the phlogiston theory by discovering phlogiston itself. No wonder he believed in this theory!

Though Lavoisier could not explain these phenomena, he could raise one important question. If the phlogiston left the metal in this process, why did the calx then weigh *more* than the metal? This supposed phlogiston had weight; Cavendish had weighed it. When it flew out, the remaining calx should therefore weigh less than the metal. Instead, it weighed more. Nor was he satisfied with the compromise of De Morveau that the gain in weight was caused by the fact that phlogiston possessed the spirit of levity.

He could find no answer to the logic of Cavendish. Study inflammable air as he might, he came away still perplexed. He burned inflammable air expecting to get, thereby, fixed air, but he got not the slightest trace. He expected to get an acid; he got none. By collecting a vessel full of inflammable air and causing a jet of pure air (oxygen) to burn in it, he reversed

nature's process. It was no novelty to burn inflammable air in an enveloping atmosphere of pure air, but here was pure air burning in an enveloping atmosphere of inflammable air. Yet, what did he get when he burned one of these gases in the other? The gases simply disappeared into space.

This was not in accordance with Lavoisier's famous principle of conservation of mass. There must be something left, and there was! Lavoisier missed it. When he finished the experiment, there must have been a mist on the inside of his vessel. Alas for Lavoisier, theory blinded him to the observation of facts which seemed unimportant to his problem. He had failed to grasp another opportunity for fame!

Lavoisier must wait again until others pointed the way, the new way. He must let Priestley, Watt, and Cavendish find the clues. But once the evidence was in his hands, he would cast it in a new mold and fit it into the framework of his new theory. The discovery which Cavendish regarded as a final substantiation of the phlogiston theory would become in the hands of Lavoisier the last link in the proof of the new oxygen theory.

Priestley had a considerable part in the famous controversy over water; in fact, he unconsciously started it. With his love of spectacular experiments, he took great delight in startling his friends with the explosion of mixtures of inflammable and common airs. "It was," he said, with accustomed frankness, "a mere random experiment made to entertain a few philosophical friends, who had formed themselves into a private society, of which they had done me the honor to make me a member."

The "private society" which had honored Priestley with membership was the famous Lunar Society of Birmingham which met one evening a month when the moon was at its brightest and the dark streets of the city could be traversed without danger to limb and neck. Among the members were some of England's leaders in science and industry. Shy, dreamy, yet strangely efficient James Watt was there. So, too, was Josiah Wedgwood, crony of Priestley and originator of famous Wedgwood pottery. Erasmus Darwin, scientist himself, and forebear of a famous line of scientists, was an active mem-

ber, as were Matthew Boulton, partner of Watt, and Thomas Day, author and ardent American sympathizer.

To entertain his "few philosophical friends," the intrepid Priestley mixed inflammable air with common air in a sealed glass vessel; then, with the aid of a spark from a friction machine he exploded the mixture. After the explosion—if the flask remained intact—there was a "dewy" substance on the inside walls. Priestley, curious observer that he was, noted the fact even though he attached no importance to it. Priestley's friend, John Waltire, tried the experiment and also noted the dew.

It was now Cavendish's turn to take up this interesting experiment. When he read, in London, of the experiments of Priestley and Waltire, he decided that they might "throw great light on the subject [he] had in view" of determining the "cause of diminution which common air is well known to suffer by all various ways in which it is phlogisticated and to discover *what becomes of the air thus lost or condensed.*" He was starting on the problem which was puzzling Lavoisier. He had what Lavoisier lacked, a clue in this dew observed by Priestley and Waltire. He was curious to find out what this dew might be and just where it came from; he exploded large amounts of the two airs and finally obtained enough of the liquid to test. Tersely and with no Priestlian superlatives, he states his results. The dew "had no taste or smell, and . . . left no sensible sediment when evaporated to dryness; neither did it yield any pungent smell during the evaporation; in short, it seemed pure water . . . and by this experiment it appears that this dew *is* plain water, and consequently, that almost all the inflammable air and about one-fifth of the common air are turned into pure water."

This was the startling fact which Cavendish had discovered by 1781. Water was formed when inflammable air and part of the common air united. He then proceeded to explode mixtures of inflammable and *pure* air and found, as he quite expected, that practically all of the airs disappeared, leaving nothing but water and that *the weight of the water was practically equal to the weights of the airs used.* Such results would puzzle Priest-

ley; phlogiston and dephlogisticated air ought to yield common air, not water.

There was one other thing which puzzled Cavendish. Sometimes the water obtained was slightly acid, sometimes not. He must find out the cause of this acidity before announcing his results to the world. Perhaps the two airs did unite to produce an acid instead of water. This would fit in with Lavoisier's theory. But no! The more he worked on the problem the more he became satisfied that nothing but pure water was produced. It was a delicate job to find out what caused the acidity, but Cavendish was not to be denied. He found that a small trace of mephitic or phlogisticated air (nitrogen) present in the pure air produced the acidity.

Cavendish was not the man to stop midway on any problem; nor did he stop now till he had solved the problem of the source of this acid. It was, he found, formed by the sparking of pure and mephitic airs together and the acid produced was nitric acid. Thus, the nature of spirits of nitre and the various nitres was solved by the painstaking efforts of meticulous Cavendish. Mephitic air, source of nitric acid, would soon become known as nitrogen. It was first studied by Daniel Rutherford. Not only this, but Cavendish also showed the world how to make nitric acid synthetically directly from the atmosphere. Worlds at war must have nitrates! The method suggested by the work of Cavendish has given way to more efficient methods; but even for these, Cavendish blazed the trail with his pioneering work.

The accuracy with which Cavendish worked is no better shown than in this bit of research. Nor is there any better illustration of the *importance* of accurate observation even of trivial and apparently unimportant facts. Cavendish found that when common air was sparked with pure air and the acid thus formed was dissolved in water, there always remained a trifling residue of gas which no amount of sparking could convert into acid. It amounted to but one 120th part of the original volume. Anyone but Cavendish would have said finis. Not so, Cavendish; he carefully noted this small residue in his notes.

A little more than a century later, Lord Rayleigh, who had been in charge of the famous memorial Cavendish laboratory at Cambridge, in conjunction with Sir William Ramsay, was searching the atmosphere for a new and unknown gas predicted by the famous periodic table of Mendeleeff. Then Rayleigh came across the century-old experiment of Cavendish, almost forgotten in the intervening time. Here in this trifling residue was the key to the problem. Quickly, Rayleigh repeated the old experiment: he isolated from the atmosphere the new gas, argon (the lazy). This made up almost precisely the one 120th part predicted by the experiment of Cavendish—but not quite. In the infinitesimal residue still left, Ramsay, Rayleigh, and Travers found a whole family of these rare but useful gases: helium (element of the sun), neon (the new), krypton (the hidden), xenon (the stranger).

Though Cavendish was far from ready to announce to the world in 1781 his incomplete results on the composition of water, he did inform some of his friends of the surprising results. Blagden, his assistant, knew of them; so did Priestley. At least, Priestley knew that Cavendish had been working on the problem. But he was far from understanding or interpreting the results as Cavendish did. If Cavendish's results were correct, then it should be possible to convert water into pure air by merely driving out the phlogiston, reasoned Priestley. On December 26, 1782, he wrote to his friend, Watt: "I have the pleasure to inform you that I now convert water into air—in the greatest quantity and with the least possible expense. The air is of the purity of that of the atmosphere. . . ."

Amazing! Priestley was transmuting water into air—so he thought. He had every right to be excited about this remarkable discovery. But nature and an earthenware retort from the factory of Josiah Wedgwood were tricking the enthusiastic discoverer. When he heated water in the retort, the water vapor passed out through the pores and air passed in; he started with water and ended up with air. He changed water into air; Cavendish changed air into water. The cycle was complete.

Now Priestley decided to repeat Cavendish's experiment and in so doing he committed blunder after blunder. The inflam-

mable air he obtained by burning charcoal instead of by treating metals with acids. To his mind (and to the minds of most) all inflammable airs, no matter what the source, were the same. Priestley was using carbon monoxide instead of hydrogen for his inflammable air, and carbon monoxide gives not water but fixed air or carbon dioxide when it burns. Most amazing, however, was the fact that Priestley *got* water from the explosion of this gas with pure air—at least he so reported. He might far better have confined himself to the production of gases. There he was a master. He must have been chagrined in 1799 when he himself made the discovery that inflammable air from charcoal was not hydrogen but carbon monoxide. He was definitely chagrined when he discovered shortly that his earthenware retort had tricked him—which he learned when he found that in a glass retort he got no air from water. He wrote to Watt, "Behold, with surprise and indignation the figure of an apparatus that has utterly ruined your hypothesis, and has rendered some weeks of my labour in working, thinking and writing almost useless."

James Watt was deeply interested in Priestley's experiments on water and air. He, too, from his observations on steam engines had become convinced that water could be changed into air. No doubt he had learned from Priestley something of Cavendish's work. It is quite certain, however, that he did not know Cavendish's clear conclusions. But the more Watt thought about the matter, the more he became convinced that it was not a mere transmutation of air into water, but a union of two airs to produce water.

Watt, the engineer, was arriving at his conclusions largely by the process of theorizing. On April 21, 1783, he wrote to his good friend, Dr. Black, "Dr. Priestley has made many more experiments on the conversion of water into air, and I believe I have found out the cause of it; which I have put in the form of a letter to him which will be read at the Royal Society with his paper on the subject. . . . Water is composed of dephlogisticated and inflammable air—and [that] dephlogisticated or pure air is composed of water deprived of its phlogiston?"

There is no denying that Watt had discovered the truth. Stripped of phlogiston verbiage, Watt was stating that hydrogen (inflammable air) unites with oxygen (pure air) to form water. Yet Watt's conclusions were based on the unsound premises of Priestley; he had performed no definitive experiments on the subject himself. Here, however, was the first semipublic announcement of the facts. On this basis rests the claim of Watt to the discovery of the composition of water.

Watt's letter to Priestley was not read at the Royal Society meeting till much later; in fact, not till after Cavendish had made his results public, for Watt had seen fit to withdraw the letter in view of Priestley's "ugly experiment." His courage failed him even though, as he said, his hypothesis was not "founded on so brittle a basis as an earthen retort."

Watt first learned of Cavendish's public announcement from the pen of M. Deluc. This gentleman, who clung to the fringes of philosophical society in both France and England, was reader to Queen Charlotte and something of a gossip-monger of science. After reading Cavendish's paper, he wrote to Watt in great excitement: "He expounds and proves your system, word for word, and makes no mention whatever of you." Watt was greatly disturbed. He replied: "As to what you say of making myself *des jaloux,* that idea would weigh but little; for, were I convinced that I had had foul play, if I did not assert my right, it would either be from a contempt of the modicum of reputation which could result from such a theory; from the conviction in my own mind that I was their superior; or from an indolence that makes it easier for me to bear wrongs than to seek redress. In point of interest, in so far as connected with money, that would be no bar; for, though I am dependent on the favour of the public, I am not on Mr. C. and his friends; ***and could despise the united powers of the illustrious house of Cavendish,*** as Mr. Fox calls them. . . . At present *Je me sens un peu blessé;* it seems hard that in the first attempt I have made to lay anything before the public, I should thus be anticipated." Had Watt, at that time, known the real character of the simple shy Cavendish, he would have had no wish to despise "the illustrious house of Cavendish."

Characteristically, Cavendish said nothing; there was nothing which needed saying and he had no friends with whom to correspond. His conclusions came from his own experimental labors and needed no defending. He had reached his conclusions before Watt started to think about the problem. But shyness compelled him to wait till he could be assured that there was no weakness in his results before publishing them. He did not know Watt personally, and when he did meet him the following year not one word was spoken by either of these shy men on the subject of their part in the great controversy. But both agreed that the conduct of Lavoisier was unbecoming. It was indeed characteristic of Cavendish that he had nothing to say on this matter. He said less and wrote fewer words than any scientist of his generation. The superlatives of Priestley, the creative imaginings of Lavoisier were totally lacking; his terse words and concise conclusions gave no clue to his thought processes but spoke volumes for his skill and accuracy as an experimenter.

Personally, Cavendish was a meager mixture of negatives. Scion of the powerful house of Cavendish and successor to his father's titles and wealth, he was reared parsimoniously, and parsimonious he remained till death. Wittily described by Berthollet as "wisest of the rich men and richest of the wise," he went about garbed in a knocker-tailed periwig, a long, faded coat and a three-cornered hat, all reminiscent of a century past. So little did he concern himself with money matters that he threatened to remove his accounts from the hands of bankers who bothered him with queries as to what to do with his rapidly mounting dividends.

His life was given over to methodical routine that he might have more time for experimentation. One of his many houses, situated in Dean Square, Soho, he turned into a library. Here he drew books as any other patron might, signing for them and carefully returning them on time. His family mansion at Clapham became a laboratory of science where neither women nor strangers were permitted to see him. The household was run frugally with the proverbial leg-of-mutton for dinner.

The one regular pleasure in a passionless life was attendance at the weekly dinners of the Royal Society Club at the Crown and Anchor. Since he never took vacations away from London, he was always there and in the last full year of his life, at the age of eighty, he attended the full fifty-two of these weekly dinners.

His morbid shyness was such that he rarely went out socially. Occasionally, however, he attended a reception given by Sir Joseph Banks, president of the Royal Society. There is an illuminating story extant of his behavior at one of these soirées. Dropped at the portals of the mansion from his sedan chair and garbed still in knocker-tailed periwig and faded blue coat, he stands timorously on the landing afraid to face the crowd within. The arrival of more guests forces the strange awkward creature forward. He enters and moves from group to group, clinging to the edges, hoping to hear a little conversation he can comprehend and shambling away quickly when someone turns to him or recognizes him as the great Cavendish. Finally, he is espied by the celebrated physician to Emperor Joseph of Austria, Jan Ingenhousz. With Ingenhousz was a distinguished foreign philosopher whose greatest desire while in London was to meet the famous Cavendish. The foreigner addresses a few flattering remarks to the embarrassed Cavendish. It is too much. With a shrill cry of terror, the world-famous scientist turns and flees awkwardly from the mansion.

Even Wilson, careful biographer of Cavendish, could find nothing uplifting about this soulless man. "Morally," writes Wilson, "he was a blank and can be described only by a series of negations. He did not love; he did not hate; he did not hope; he did not fear. . . . There was nothing earnest, enthusiastic, heroic or chivalrous in his nature and as little was there anything mean, grovelling, or ignoble. He was almost passionless. . . . His brain seems to have been but a calculating machine; his eyes, inlets of vision, not fountains of tears; his hands, instruments of manipulation which never trembled with emotion, or were clasped together in adoration, thanksgiving or despair; his heart only an anatomical organ, necessary for the circulation of blood. . . . He was not a poet, a priest or a prophet, but

a cold clear intelligence raying down pure white light which brightened everything on which it fell but warmed nothing."

Such was the man who shambled awkwardly about dressed in the garb of generations past, weighing and measuring the world and everything in it. If he was not the first luminary in science, he was certainly the second. With his nature devoid of all human passion some would regard him as the very epitome of cold, logical science itself. But true science through the ages has raised passions, produced fervor, broadened imagination, has created from fancy and moved forward in minds which could feel as well as see, build as well as decompose, theorize as well as analyze. Cavendish's life was pitifully lopsided. He was no match for Lavoisier in those qualities which called for enthusiasm for a cause, and willingness to fight for it. Once through with a problem, Cavendish stood aside and let the world accept or reject as it chose.

Did Antoine Lavoisier know what problem his famous contemporary was working on in London? Did he know what important conclusions had been reached in that experiment? The answer of history is "yes." News and gossip travelled across the Channel in the 1780's with great speed in spite of slow diligences and slower boats. Samuel Johnson said, "Blagden, sir, is a delightful fellow." Delightful fellows are those who enjoy spreading news. It is not surprising to find Blagden, who had just been elevated from his post as assistant to Cavendish to that of secretary of the Royal Society, a visitor in Paris in June 1783. Nor is it surprising to see this same gentleman in the Arsenal, at another famous Lavoisier dinner. Blagden talked of the work his master had been doing and of the significant conclusions reached. Water was not an element! Blagden should never have talked, but he enjoyed the importance vested in him as the messenger of startling news.

Was Lavoisier startled? Blagden says he was. "So far was M. Lavoisier from thinking any such opinion warranted, that, till he was prevailed upon to repeat the experiment himself, he found some difficulty in believing that nearly the whole of the two airs could be converted into water." Blagden wrote this where all the scientific world would be sure to see it—in Caven-

dish's manuscript on water. The passage is there in Blagden's own hand but purporting to be a statement by Cavendish, for it bears the following prelude also in Blagden's hand. "During the last summer, also, a friend of mine gave some account of them [the experiments] to M. Lavoisier as well as the conclusions drawn from them."

For interpolating this statement into Cavendish's manuscript, Blagden has been abused by some and defended by others. But he felt duty-bound to cover up the error he had made by his premature announcement. The French chemists, and most of all, Lavoisier, had a habit of using the facts of others for their own purpose.

Yes, Lavoisier was surprised at what Blagden told him but Blagden did not go on to say *why* Lavoisier was surprised. It was not the fact that the two airs united which surprised Lavoisier, it was the fact that *pure* water, instead of an acid, was obtained by a union involving oxygen. To Lavoisier, oxygen was the acidifying principle and when it united with things other than metals the product should be an acid.

Nor was it necessary to *prevail* upon Lavoisier to repeat the experiment as Blagden would have it. He was quite willing, nay, anxious to repeat it. On Tuesday, June 24, 1783 with Laplace assisting, Lavoisier repeated this striking experiment in the presence of Blagden, Vandermonde, Fourcroy and Meusnier. Cavendish was right! The product was pure water, not an acid. It was a blow to Lavoisier's theory of oxygen as the acid-former. This was, in fact, the only detail in which Lavoisier's new theory was unsound.

The minutes of the meeting of the Academy of Science for Wednesday, June 25, 1783—the day following the experiment—show the following interesting entry: "MM. Lavoisier and de Laplace announced that they had lately repeated the combustion of Combustible Air with Dephlogisticated Air; they worked with about 60 pints of the airs, and the combustion was made in a closed vessel: *The result was very pure water.*" It was the first public announcement of these important facts. No mention of Cavendish or Blagden here! In the memoir when it appeared, however, mention was made of both. "It was on the

24th of June that M. de Laplace and I made this experiment in the presence of MM. Fourcroy, Vandermonde, and several other academicians and of Mr. Blagden, Secretary of the Royal Society of London. *The latter informed us* that Mr. Cavendish had already tried, in London, to burn inflammable air in closed vessels, and that *he had obtained a very sensible quantity of water*." Full recognition of priority, it would seem!

Blagden, however, was far from satisfied with this statement. Indignant, he later wrote a long and somewhat abusive letter to be published in Crell's *Annalen*. He said in part: "I can certainly give you the best account of the little dispute about the first discoverer of the artificial generation of water, as I was the principal instrument through which the first news of the discovery that *had already been made* was communicated to Mr. Lavoisier. . . . In general, Mr. Lavoisier cannot be convicted of having advanced anything contrary to truth; but it can be still less denied that he concealed part of the truth; for he should have acknowledged that I had, some days before, apprised him of Mr. Cavendish's experiments, instead of which the expression *il nous apprit* gives rise to the idea that I had not informed him earlier than that very day. In like manner, Mr. Lavoisier has passed over a very remarkable circumstance—namely, that the experiment was made in consequence of what I had informed him. He should likewise have stated in his publication not only that Mr. Cavendish had obtained *une quantité d'eau très sensible* but that the water was equal to the weight of the two airs added together. . . ."

Watt, too, was upset by the news of Lavoisier's announcement. In November 1783 he wrote to Deluc, "I was at Dr. Priestley's last night. He thinks as I do that Mr. Lavoisier, having heard some imperfect account of the paper I wrote in the spring [the paper was withdrawn before publication], has run away with the idea and made up a memoir hastily, without any satisfactory proofs—I, therefore, put the query to you of the propriety of sending my letter to pass through their hands to be printed; for even if this theory is Mr. Lavoisier's own, I am vain enough to think that he may get hints from my letter, which may enable him to make experiments and to improve his

theory, and produce a memoir to the Academy before my letter can be printed, which may be so superior as to eclipse my poor performance, and sink it into utter oblivion, nay, worse, I may be condemned as a plagiary, for I certainly cannot be heard in opposition to an academician and a financier. But after all, I may be doing Mr. Lavoisier an injustice."

Again Watt wrote angrily of both his rivals, "I have had the honour, like other great men, to have had my ideas pirated. Soon after I wrote my first paper on the subject, Dr. Blagden explained my theory to M. Lavoisier at Paris [it was Cavendish's theory that Blagden explained], and soon after that, M. Lavoisier invented it himself, and read a paper on the subject to the Royal Academy of Sciences. Since that, Mr. Cavendish has read a paper to the Royal Society on the same idea without making the least mention of me. The one is a French financier; and the other a member of the illustrious house of Cavendish, worth above 100,000£., and does not spend 1000£. per year. Rich men may do mean actions."

That Lavoisier was attempting no serious claim to priority is evidenced by the tone of a letter which Lavoisier's good friend, Laplace, wrote to Blagden in 1785. "We are much occupied here now," he wrote, "*with the great discovery of Mr. Cavendish on the composition of water.* Mr. Lavoisier is studying the problem as accurately as is possible. He has repeated the experiment of burning dephlogisticated air in inflammable air and finds, as did Mr. Cavendish in his excellent work, that no nitric acid is formed."

In view of the evidence, why have some historians and biographers insisted on claiming priority for Lavoisier in this notable discovery? Any implied claim arising from early work on inflammable air could certainly form no reasonable basis. The real answer may be found in the words of Marcelin Berthelot, distinguished biographer of Lavoisier, when he says, "This, I venture to repeat, is an incident in the long-standing feud, continually being renewed in the history of science, ***between the sagacious discoverers of particular facts and the men of genius who frame general theories.*** " The answer is to be found in the fact that Lavoisier, the theorizer, placed the facts

of Cavendish, the discoverer, in a wholly new and rational light.

Cavendish's conclusions were entangled with the terminology of phlogiston. At one time, he regarded phlogiston as identical with inflammable air; at another, the two were separate entities. Yet, the truth was there, needing only the removal of phlogiston shrouds to make it clearly evident. Cavendish was well aware of Lavoisier's new theory. He even attempted in his memoir to show how Lavoisier would state the case. But this seemed so unsatisfying and foreign to him that he returned to the phlogiston concept in the end as the most reasonable explanation.

On Lavoisier's part, there was no hesitation; phlogiston he discarded as unessential and unreal. Inflammable air was, like pure air, an element. He named it hydrogen (water-former). The formation of water was naught but a union of hydrogen and oxygen gases, a combustion in oxygen similar to any other combustion. Says Wilson, biographer and defender of Cavendish, "Lavoisier's conclusions, however, whether he was entitled to them or not, were stated with a precision and clearness to which the announcements of Cavendish, Watt and Monge cannot lay claim. (Monge, independently, had performed an experiment much like that of Cavendish and had arrived at similar conclusions in the summer of 1783. He claimed no priority.) They are contained in two brief, but emphatic lines: 'Water is not a simple substance, but is composed weight for weight of inflammable and vital air.' " He added, "What was especially his, was the precise definition of the combustible element of water (hydrogen), as a peculiar gas having the physical properties of other gases, and the ordinary attributes of matter, so that the halves of water were physically similar though chemically unlike. This seemed to Cavendish, who commented on it in the close of his own paper, a slight alteration and a very doubtful improvement on his own view. To us, it appears in a very different light. Lavoisier's merit was assuredly very great."

In assigning credit for the discovery of the composition of water, the painstaking researches of Wilson on the matter are

most significant; his conclusions seem just. The claims of Watt must be disallowed as based on faulty evidence, though his shrewd deductions show the workings of an alert mind. Likewise, the claims of Lavoisier to the original discovery must be disallowed. For the correct interpretation of Cavendish's clouded conclusions, however, Lavoisier must receive full credit. He, and he alone, understood them. He, and he alone, was unafraid to face the consequences of a new interpretation and regiment these hazy facts into a new front of crystal clearness and amazing simplicity.

Lavoisier had at last found the answer to the problem which had puzzled him. He knew the source and nature of this queer inflammable air. It was not phlogiston, it was an element; it had weight; when metals were treated with acids, it came from the water in the acid, not from the metal; and the other part of the water, the oxygen, remained behind to form a calx with the metal. This was what caused the increase in weight! It was Lavoisier who taught us what water really is, not Cavendish, or Watt, or Priestley. He discovered neither oxygen nor the composition of water, but he was the only man of his day who understood what they were.

Nor was Lavoisier content to let matters stand. If water were, in truth, a compound of hydrogen and oxygen, it should be possible to obtain hydrogen from it. Iron would rust under water or in moist air. This, according to Lavoisier's theory, meant that the iron united with the oxygen of the water, forming a calx and setting the hydrogen gas free. It should be possible to collect the gas and determine if it really were hydrogen. A gun barrel containing iron filings was placed in a furnace. Steam was admitted at one end while the other was attached to a gas receiver. Lavoisier's surmise was correct: the issuing gas was hydrogen. The material remaining in the gun barrel was calx of iron (oxide of iron).

Cavendish had synthesized water; Lavoisier had decomposed it. Both processes could be explained by the use of the phlogiston theory but henceforth only the older men, the conservatives of science, would do so. The younger men, their ranks strengthened by the conversion of Black, would go forth

under a new banner. The master could turn his attention to other ramifications of the new theory and lay the foundations of modern physiology and organic chemistry. Single-handed he had fought. Now victory was within his grasp, but he must still fight: fight those who would absorb and divide his laurels among themselves; fight to convert the unbelievers, the scoffers, the jealous and the envious.

Triumph of a Theory

A DECADE had passed since Antoine Lavoisier had cast the first stone at the phlogiston theory in 1774. Among chemists he still stood alone, fighting a solitary battle. Only the mathematicians, Laplace and Lagrange, had rallied to his cause. Before turning his case over to the jury of science he must give a summing up of the final arguments all aligned in proper sequence. He must show that his theory was more universal in its application than that of Stahl.

Life itself must be subjected to the balance pan, the retort, must be shown to obey the simple laws of chemistry. Since the dawn of Christianity, the Church had said, "Hands off! Life is sacred; it must not be investigated by science." Vesalius had answered the threat with dissection of corpses in hidden cellars. He had discovered much but not the cause of life processes. Stahl had said that life was controlled by a "vital force." What was "vital force"? It was a statement but not an answer to life processes. Life, according to Xavier Bichat, consisted of the sum of the functions which resisted death—an excellent definition which said nothing; it could never satisfy the logical curiosity of Lavoisier.

Why did man breathe? Why was his body warm even in frigid environments? Was respiration, as Haller taught in his *Elements of Physiology*, a mere mechanical pumping process which forced blood to circulate through the abdomen and heart? Was animal heat, as the popular physiologies of the day taught, produced by the friction of the blood coursing through the veins? Or was it "inborn" in some occult way, the product of "soul-life spirit"?

Such was the state of conjecture in the science of physiology before Lavoisier boldly opened the door of the animal body to show how it worked. He is as truly the father of modern physiology as he is the father of modern chemistry. "He laid the foundations of physiological chemistry in such completeness that successors could build additions to this structure but for many years could not make any material changes. . . . He struck the first blow at 'vitalism' which was finally killed by Wöhler in 1827," says Hemmeter.[12] He says further that, though physiologists frankly credit this to Lavoisier, chemists have been slow to recognize it. "This path," he adds, "has been largely planned and laid out by Lavoisier so that but one, it is true the boldest achievement, was needed to reach the climax and that was by keen research to confirm the law of conservation of energy. Lavoisier was working on that problem when he died and might have saved thirty years or more for the advance of organic and physiological chemistry had he lived."

Borrowing Black's ideas on latent heat and Priestley's conjecture concerning breathing (and being sharply criticized once more for apparent failure to give credit where credit was due), Lavoisier proceeded with Laplace to study the relation of animal heat to breathing. A vessel containing pure oxygen was placed in another, well insulated, containing ice. Into the inner vessel went a protesting guinea pig—to breathe pure oxygen and record the amount of heat produced by the amount of ice melted. Lavoisier was convinced that the function of breathing was not a mere mechanical one but a chemical one. The oxygen introduced into the lungs united with carbonaceous matter of the blood (either in the lungs or the blood vessels, Lavoisier couldn't decide which) to produce fixed air or carbon dioxide which was then exhaled from the lungs. The amount of carbon dioxide thus produced could be determined with the limewater test, the amount of heat by the quantity of ice melted. The next step was to substitute a calculated amount of pure carbon for the guinea pig. With a burning glass, the carbon was ignited.

[12] Hemmeter, John C., *Lavoisier*, p. 7. Baltimore: Society of Medical History, Johns Hopkins University.

Reasoned Lavoisier: If body heat is produced by a process of slow combustion of carbon in the body, then the total amount of heat should be the same when an equivalent quantity of carbon is burned in the vessel. The results were somewhat surprising, for the guinea pig proved to be more efficient than the pure carbon, the life process of combustion produced more heat than the inanimate process. Not till he had analyzed organic compounds and discovered that they contained hydrogen as well as carbon could Lavoisier explain the discrepancy—he had failed to allow for the fact that the hydrogen as well as the carbon burns in the animal body. The one process produces carbon dioxide, the other, water.

The function of respiration was explained at last. It was not a mere mechanical process—a pumping of blood—nor was it an "inborn" matter, a "life-spirit," a mysterious "vitalism." It was a simple chemical process involving slow combustion of living tissues. Just as wood burned in air, so man burned foods in his body, with the aid of oxygen; it was not a matter of giving off phlogiston.

Lavoisier also saw, and clearly, the whole economic interdependence of plants and animals. Materials for the building up of plant tissues came, he argued, in the last analysis from air, water and minerals; the organic material built up by the plant served as food for animals. Combustion, fermentation and decay were merely processes of returning these organic materials, as simple substances, to the air and the earth once more. Priestly had also shown that plants could purify bad air. Vegetation and animalization were, he saw, the inverse phenomena of combustion and putrefaction. In the one process, organic materials were built up; in the other, torn down.

The complete mechanism of these processes, he did not, of course, understand—nor do we today. We have progressed further toward a solution; but the basic principles enunciated by Lavoisier are still valid in every respect.

Shortly before his death, Lavoisier and Séguin were making a complete study of respiration and transpiration, using a most novel method. This time the experimental animal was a human being, Séguin. A varnished silk bag was made to fit

him; it was carefully weighed, then fitted over his body. The only opening was at the mouth. Through a tube, Séguin breathed in oxygen from a reservoir of the gas. His expired air was caught in another vessel to be analyzed for its content of oxygen, moisture, and carbon dioxide. Séguin, himself, was carefully weighed both before and after the experiment. Thus, did Lavoisier apply his law of conservation of mass to the study of human metabolism. It was a crude experiment to be sure, but it was a forerunner of modern studies of metabolism. There is extant a sketch of this strange experiment done by the skilful hand of Mme. Lavoisier. This work was never finished and the world was forced to wait many more years for studies in metabolism. Though Lavoisier never expressed it, his work indicates that he understood the significance of the great law of conservation of energy almost as well as his expressed law of conservation of mass.

Assisting Lavoisier in his early studies of respiration was Pierre-Simon Laplace. It was Laplace, too, who assisted in the famous experiment on water. Though Laplace made no pretentions to being a chemist, he was nevertheless interested in all science. The field which claims him as an outstanding leader is applied mathematics. With his great contemporary, Lagrange, he holds a high place in the history of mathematics, being regarded by some as "the Newton of France." Both of these men were frequent guests at the Arsenal and lifelong friends of Lavoisier. Both Laplace and Lagrange escaped the guillotine.

Laplace's life was a queer mixture of bigness and littleness, genius and blunder, vanity and humility. Born of most humble parentage, he gained early fame as a mathematician under the guidance of D'Alembert. Academician by the age of thirty, he had already undertaken the stupendous task of proving that the solar system was a stable one which swung in endless cycles back on itself in a panorama of perpetual motion. His clear brilliant writings were nevertheless difficult for a less brilliant mind to follow and when he wrote "it is easy to see," the reader was certain to groan, for there always followed an exposition of mathematical reasoning which would take hours to unravel.

Strangely enough, Laplace is best known in the modern world for the famous Laplacian hypothesis of the origin of the solar system, which theory he proposed, half in jest, half seriously in a brief note at the end of one of his papers.

From an unknown boy of humble origin to scientist under Louis XVI, to republican under the Revolution, to marquis under Napoleon, to peer under the restoration of the Bourbons, Laplace rode the changing tide of political waters shifting his allegiance to suit the times. Favorite of Napoleon, he nevertheless voted for the exile of his emperor—when it seemed the proper thing to do. Yet, he was one of few men unafraid to talk back to the little Corsican.

There was something about both Laplace and Lavoisier, something which struck a friendly rhythm between them. Both were theorists and worked with ideas, both had keen analytical intellects coupled with imagination; and since they worked in different fields there arose no jealousies to separate them as Lavoisier was separated from some of his chemist colleagues. Laplace was the first scientist to espouse Lavoisier's oxygen theory. There was also a similarity less pleasing to contemplate: both had personal ambitions for glory in science which carried them beyond ethical bounds; both were accused of scientific plagiarism more than once. Their excuse was that they saw in the works of other men far more than the authors saw, and used such works to develop their larger concepts.

The time had come to rewrite the whole science of chemistry. The one man capable of doing it was Antoine Lavoisier. But he needed helpers in the stupendous task, men who could thoroughly believe in his new system, who could help him with the details, who could carry forth the gospel of the new science. They must be chemists, not mathematicians or astronomers. Where should he turn for support? Baumé, Sage, Priestley and Cavendish were active, even bitter in their opposition. Black, and Macquer had little to say. Guyton de Morveau of Dijon, leading chemist of the provinces, had written his Encyclopedia articles on chemistry without mentioning the oxygen theory. He had even countered Lavoisier's arguments by proposing that phlogiston possessed the spirit of levity. Nowhere was

there a chemist who looked with more than a sceptical eye at this strange new theory.

De Morveau was the key man Lavoisier must win to his cause. He was proposing a new nomenclature for chemistry to replace the antequated alchemical terms. He had access to the public through the Encyclopedia. It speaks well indeed of Lavoisier's eloquence that De Morveau after a visit to the Arsenal changed his whole attitude; from bitter opponent he became enthusiastic apostle. It speaks well for De Morveau's intelligence that he could thus change his whole mode of chemical thinking.

De Morveau, like Lavoisier, was a strange mixture of scientist and economist. A native of Dijon and son of a successful advocate, he followed his father's career in the parlement of Dijon. Like Lavoisier, however, his first love was always science, and in 1782 he turned his back on the law to devote his full time to science, becoming professor of chemistry in the University of Dijon.

Arthur Young paints a graphic picture of the great Dijon chemist at the height of his career in 1789. "The great and just reputation of Mons. de Morveau, for being not only the *first chemist* of France, but one of the greatest that Europe has to boast, was alone sufficient to render his company interesting; but such a man void of affectation, free from those airs of superiority which are sometimes found in celebrated characters, and that reserve which oftener throws a veil over their talents, as well as conceals their deficiencies for which it was intended —was very pleasing. Mons. de Morveau is a lively, conversable, eloquent man, who, in any station of life, would be sought as an agreeable companion. Even in this eventful moment of revolution, the conversation turned almost entirely to chymical subjects. I urged him as I have done Dr. Priestley more than once and Mons. Lavoisier also, to turn his enquiries a little to the application of his science to agriculture—to which he assented; but added, that he had not time for such enquiries: it is clear from his conversation that his views are entirely occupied on the means of establishing the new nomenclature."

It is interesting to note that Young ranks De Morveau as the most eminent chemist in France at a time when Lavoisier's theory was just reaching success. History has never accorded De Morveau this high rank. Was Young affected adversely by the personality of Lavoisier or was it that Lavoisier's laurels were already being absorbed by the so-called "French Chemists"?

In De Morveau's life there was but one woman, the brilliant gentle Madame Picardet, wife of a Dijon academician. "Madame Picardet," says Young, "is as agreeable in conversation as she is learned in the closet; a very pleasing unaffected woman; she has translated Scheele from the German and a part of Mr. Kirwan from the English [this translation is usually attributed to Mme. Lavoisier though there may have been some collaboration between the two women]; a treasure to M. de Morveau for she is able and willing to converse with him on chymical subjects, and on any others that tend either to instruct or please." If Mme. Picardet was the mistress of the chemist it was with the apparent approbation of her husband, for Young notes that he enjoyed a most pleasant dinner with the two, Picardet and De Morveau. Upon the death of his colleague, Picardet, De Morveau, now approaching sixty, married the widow.

It must have been a strange and perverse fate which carried De Morveau into the thick of the political revolution and placed him on the far left. There is nothing in his background which would suggest the excesses of which he is accused. Robison, Black's editor, says, "He was a commissary of the Convention; and persecuted with the most cruel virulence the noblesse of his province, who had twice paid his debts and had given him twenty-four thousand livres to enable him to prosecute his chemical enquiries." This statement is undoubtedly exaggerated.

Even before De Morveau had been won to the cause of the new chemistry, young Antoine Fourcroy had accepted the gospel. A brilliant speaker and writer, a popular teacher of chemistry, Fourcroy did much to popularize the new theory. Son of a poor branch of a noble family, he was raised among the

sansculottes of Paris where his father held a humble position as pharmacist to the Duc d'Orléans. Through his father's friendship with Vic d'Azyr, secretary of the Academy of Medicine, the promising lad was assured of a medical scholarship. But this academy refused to grant him the degree of *docteur régent.* Fourcroy did not forget, nor did he forgive this slur. The Academy would have good cause to remember it, too, at a later date.

Fourcroy's eloquent teaching won him Macquer's attention and on the death of the grand old man, in 1784, he was appointed, on Lavoisier's recommendation, to Macquer's post in the Jardin du Roi. For twenty-five years he taught chemistry there, attracting great crowds by his brilliance and eloquence. His writings were equally brilliant, his famous textbook in chemistry going far to establish the new doctrines after the death of Lavoisier.

As an experimenter, Fourcroy was mediocre, being "without the preciseness of Cavendish or the sagacity of Lavoisier." He was one of the ambitious young men who availed themselves of the opportunity to participate in Lavoisier's laboratory "holidays." Regularly, he was present, absorbing knowledge, assisting in experiments and working up his table of new terms. That Lavoisier had a high regard for his ability is evidenced by the fine recommendation he gave him as Macquer's successor.

Fourcroy's fame in science, however, rests on two things and only two things, his association with Lavoisier and his textbook. Without the former, moreover, the latter would have been unimportant. He lacked the organizing power of De Morveau, the experimental ability of Berthollet and the creative genius of Lavoisier.

It was Lavoisier who took Fourcroy under his wing when he was an ambitious young man; it was Lavoisier who recommended him to Bucquet for his first position; it was Lavoisier who gave him a share in the famous round-table discussions at the Arsenal; it was Lavoisier who, recognizing his brilliance in writing and speaking, chose him as one of the famous

quartet about to revolutionize the entire system of chemistry. How would Fourcroy repay this debt?

That is the story of a later day. Now he was busy and enthusiastic over the task assigned to him of drawing up a table of names for the new chemistry. He was one of the Four Horsemen who were soon to ride rough shod as the detested "French Chemists" over the old world of chemistry.

The fourth member of the famous quartet, the first chemist in France to stand beside Lavoisier and his new concepts, was Claude Louis Berthollet. In 1785 he ranged himself publicly beside Lavoisier and there he stood, staunch friend, through victory and storm. He was the best experimentalist in France and among his important discoveries were the bleaching properties of Scheele's newly discovered chlorine gas. With Lavoisier, he worked out the first successful commercial bleaching plant.

In later years, he discovered in a curious way the important effect of chlorine on wax and organic oils. Wax candles used in the Tuileries were bleached with chlorine; they gave off an offensive, suffocating odor and Berthollet discovered that the chlorine bleach had united with the wax. From this simple discovery have come countless chlorinated products in modern use.

Another important discovery made by Berthollet was that of chlorate of potash. It was this unstable compound that almost caused the death of both Berthollet and Lavoisier. Berthollet discovered that when this new compound was mixed with charcoal and sulfur, it formed an explosive mixture. This led Lavoisier to the conclusion that it might be used in place of saltpeter, which was scarce, for making gunpowder. He arranged to have a batch of the new powder made up in the factory at Essonnes.

On the morning of the experiment, Sunday, October 27, 1788, M. and Mme. Lavoisier, M. Berthollet, M. and Mlle. Chevraud drove down to Essonnes to watch the experiment. Lavoisier had instructed M. Le Tort, superintendent of the factory, to give the workmen adequate protection from the dangerous mixing vat and Le Tort had done so. The workmen stood behind a heavy plank partition. But the mixing proceeded awk-

wardly, materials being thrown upon the walls of the vat; Le Tort even had the temerity to poke the spattered masses down with his cane. Knowing full well the dangerous nature of the mixture and its response to shock, Lavoisier was disturbed. The company was gathered in the open around the vat while the workmen stood behind their barricade. It seemed like useless exposure to danger, and he suggested that the spectators retire to see the shops while the materials were being mixed.

As the group returned to the mixing mill once more, Mlle. Chevraud and M. Le Tort were in the foreground. There was a violent explosion. The two in front were hurled against the wall of the mill to almost instant death. The others, badly shaken and bruised, escaped with their lives and, thanks to Lavoisier's careful precautions, the workmen were unharmed.

In spite of the horrible results of this experiment, Lavoisier was eager to experiment further with this new powder, for its success would relieve the nation of the burden of gathering saltpeter. He wrote to the minister: "Please bring this matter to the attention of the king and let me assure his majesty that my life belongs to him and to the state. I am ready to sacrifice it at any time in his service." Fortunately, the experiment was dropped.

Berthollet rode the storm of revolution in comparative safety. With Laplace, he took over the work of making gunpowder under the new régime. With Monge, his closest friend, he worked on various scientific commissions of the Revolution. It is probable that his connection with the gunpowder work and the great need of powder for the revolutionary armies saved his neck. Upon the death of Lavoisier, he became the leading chemist in France.

Under Napoleon, both Monge and Berthollet rose to high places in affairs of state. Napoleon's fondness for science (about which he knew nothing) is well known. Every scientist who escaped the axe was well rewarded were he revolutionist or royalist. It is interesting to conjecture what position Lavoisier might have fallen heir to.

It was this little group of four, De Morveau, Fourcroy, Berthollet and Lavoisier which was conferring daily for eight

months in the Arsenal to build up the new nomenclature of chemistry. To De Morveau fell the heaviest task of working up the details; Berthollet was the field judge and Lavoisier the captain. Lavoisier's was the task of opening the attack before the sceptical Academy. It would be no easy matter to demand that chemists relinquish the ancient terminology of alchemy. At an open meeting of the Academy on April 18, 1787, he presented the introductory memoir on the subject. He credited the conception of the new naming system unmistakably to De Morveau. "Physical science," he said, "consists of three things, the series of facts that constitute the science, the ideas which represent facts, and the words which express them. Like three impressions of the same seal, the words should call forth the ideas, and the ideas the facts. . . . And, since it is the words that preserve the ideas and transmit them, it follows that we cannot improve the science without improving its language. Nor can we improve the language without improving the science. . . . The oil, the mercury, and even the water of the philosophers were neither oil, nor mercury, nor water in the sense that we understand them."

Then, Lavoisier defined an element in unequivocal terms. It was Boyle's century-old definition which had lain almost forgotten through the phlogiston era. "An element," he said, "is a simple substance which cannot be decomposed into other substances." With remarkable foresight, he predicted that the so-called fixed earths regarded by most scientists as simple substances would one day be decomposed into metals and oxygen. Twenty years later, Sir Humphry Davy fulfilled the brilliant prediction by decomposing most of these "earths" with an electric current; from them he obtained new metals.

"We have," concluded Lavoisier, "done violence to the established order that may at first seem barbarous; but we have also observed that the ear quickly becomes accustomed to new words if they are connected to a systematic order. Such words as powder of algaroth, sal alembroth, pamphalix, phagendenix water, turbith mineral, aethiops, colcothar, now in use, are equally harsh and barbarous. . . . The names, oil of tartar per deliquum, oil of vitriol, butters of arsenic and antimony, flowers

of zinc, etc., are even more ridiculous, since there does not exist in the mineral kingdom either butter, oil, or flowers, and because most of the substances designated by these fine sounding names are in reality violent poisons."

In De Morveau's carefully prepared memoir were to be found the new names which instead of veiling the substance in mystery exposed it to systematic classification. There were oxides and sulfides, acids and alkalis, salts and minerals. Each name told what the substance was in chemical composition and to which category it belonged.

So shrewd and all-inclusive was this new system based on Lavoisier's oxygen theory that it has lasted with only minor changes to the present day and bids fair to last for another century. Perhaps the little group was very lucky, as some critics suggest. Had the theory upon which the naming was based proved to be wrong, the whole system would have fallen with it. Of course! But it was not luck, it was clear foresight.

It could scarcely be expected that the new nomenclature would sweep all chemists into its fold at once. It is hard to learn a new language and forget the old in short order. Even the authors had to translate their own ideas from the old into the new. Said Thomas Thomson, harsh critic of the whole scheme, "The establishment of a new nomenclature in any science ought to be considered as high treason against our ancestors, as it is nothing less than an attempt to render their writings unintelligible, to annihilate discoveries, and to claim the whole as our own property." Are Linnaeus in botany and Lavoisier in chemistry regarded as traitors? If so, let us have more of such traitors!

In Ireland, Kirwan complained bitterly that one could scarcely distinguish the new word oxide from oxhide, the skin of an ox! Even Black, open-minded as he was, complained about the barbarous slashing of proper names and attempted to set up his own nomenclature. "Chemistry," he said, "is not yet a science. We are very far from the knowledge of first principles. We should avoid everything that has the pretension of a full system. . . ." Robison, editor of Dr. Black's famous book on chemistry, goes on to say, "He disapproved . . .

exceedingly of the entire substitution of this for all other denominations and affirmed that proper names, where they can be had, should on all occasions be preferred. . . ." He becomes both bitter and sarcastic toward the "junto of French chemists."

"A determination to be the founder of a system and a sect of philosophers," says Robison, "seems to have seduced Mr. Lavoisier and made him acquiesce in measures which may be called violent and unbecoming. As for the imitators . . . they boggled at no incongruity with common language and sentiment; and rather had a pride in it, as a mark of their authority over the opinions of other men. . . . It [the new nomenclature] has introduced into chemistry the same licentious dialect that the Aristotelian metaphysics introduced into the schools of philosophy; and will produce the same bigotry and ignorance. Had all the proper names been retained . . . Mr. Lavoisier's honours would have been fully secured to him. Newton still stands at the head of philosophers, although they still speak of the sun's path around the heavens, and retain the old astronomical language." With a Shakespearian flourish, he adds the last touch: "But Newton had no such ambition; nor did the Royal Society furnish such a legion of Honour as Mr. Lavoisier found among his fellow countrymen."

Perhaps the worst thrust of all was the faint praise given the new system by the Academy itself. On the reviewing committee were Baumé, who had just written a new chemistry book based on the phlogiston theory; Sage, last phlogistonist in France; D'Arcet, who had disagreed with Lavoisier over the combustion of diamonds; and Cadet.

"This new theory," they wrote, "is the work of four men, who are justly renowned in science and who have been long engaged upon it; doubtless, they have not drawn it up without careful comparison of the bases of the ancient and the modern theory." The definition of an element appeared to the committee "as if we were at the first moments of creation again." Truly, they were at the first moment of the creation of a new chemistry! Grudgingly, permission was granted to print the memoir in the transactions but with the specific understanding that the Academy neither approved nor rejected the scheme.

The reformers, after pointing out in rebuttal that the ancient theory was so demoralized as to be no longer a theory, rested content with this scant recognition. The ground upon which the seeds of the new nomenclature fell was barren, but not sterile. With cultivation these seeds began to sprout into lusty young plants. Young chemists with open minds began to see the great simplicity and symmetry of the new design.

Before the new chemistry could make itself felt, however, one more step was necessary. The evidences for the new theory were scattered throughout various memoirs, pamphlets and writings of Lavoisier and others. No man could see the whole sweep of the new design spread out before him with its supporting detail. Until this could be done, converts would be slow. Lavoisier decided, therefore, to write a new book, a book based on the new theory using the new nomenclature which would introduce beginners and others to the new theory in its entirety.

This book, *Traité Elémentaire de Chimie,* published in 1789, marks the real beginning of modern chemistry.

At first, he had not intended to write a complete textbook but merely to elaborate on the new nomenclature. He was driven on, however, by a crusading force to prepare a complete textbook of chemistry, modern in every sense. "I have," he said, "imposed upon myself the law of advancing only from the known to the unknown, of deducing no consequence that does not directly come from experiments and observations." This is the method which has dominated the teaching of science since Lavoisier's day.

With no discourse on the history of alchemy, with not a mention of the dominant phlogiston theory, he starts in simply and directly on his new chemistry. "This book," he said, "is neither a history of science nor a psychological treatise; it is an exposition of chemistry as it is now known."

For the first time in history there appeared a list of the known elements, not four of the ancients, but thirty-three, some metals, some non-metals, some gases. He added, "Chemistry advances toward its goal and its perfection by dividing, subdividing, and re-subdividing . . . we cannot be sure that what we regard as a simple body is really so; all we can say is that

a certain substance is the limit at which chemical analysis has arrived and that it cannot be further subdivided as far as our knowledge goes." Again he stated his scepticism of the elementary nature of such "earths" as lime, magnesia, silica, and alumina but included them as elements since they had not yet been decomposed.

Included in his list of elements were the two strange ones, light, and caloric or heat. Somehow or other, in spite of his experiments, he could not shake off the queer notion that heat was a form of matter. Strangely enough, the true nature of heat would be explained later by a man, Count Rumford, whom Lavoisier did not know, but whom Marie would come to know well.

In Lavoisier's book, too, is to be found a detailed explanation of his most famous experiment which he first presented in his conclusive memoir of 1778. He saw clearly that there was no distinction between the so-called fixed gases and those like steam which could be liquefied. For, he argued, if the earth were moved closer to the sun in a hotter region, all water would vaporize and would be regarded as a permanent gas. A generation later, Faraday, using pressure, liquefied the so-called permanent gas, chlorine, to prove, in principle, that any of the fixed gases could be liquefied. Today, all gases have been not only liquefied but solidified as well.

For the first time, too, there appeared in this revolutionary book a clear and precise statement of the great law of conservation of mass: "For nothing," he wrote, "is created in the operations either of art or nature, and it can be taken as an axiom that in every operation an equal quantity of matter exists both before and after the operation . . . we must always suppose an exact equality between the constituents of the bodies examined and those obtained by analysis. . . ."

Both Cavendish and Black had used this principle but neither had attempted to state or prove it. It is a principle which has become the very cornerstone of all chemistry; it is the principle which has made chemistry an exact science. All chemists have followed Lavoisier's lead in expressing chemical changes in the form of a simple equation in which weights of materials

used must balance weights of products; the equation is the balance-sheet of chemistry and there are neither deficits nor surpluses in this balance. "It makes chemistry," said Lagrange, "as simple as algebra."

Says McKie, "The publication of the *Traité* with its list of thirty-three elements *marks the foundation of modern chemistry.* We may have rejected Lavoisier's notion that oxygen is an essential constituent of acids and advanced far from his primitive (caloric) conception of the thermodynamics of chemical change, but the theory set out in his great treatise is in all its essentials still the fundamental theory of chemistry. What Boyle had glimpsed only distantly in 1661 had now come to pass; and the four elements . . . and all the word spinning that went with them were now swept clean away. To achieve the revolution that he had aimed at in 1773, Lavoisier had to build on the work of Black, Priestley and Cavendish, but the revolution proved far greater and struck much deeper than he had foreseen. And although he built on and improved on the work of others, Lavoisier is in every sense entitled to be named as the 'Father of Modern Chemistry.' "[13]

Written only a few years after Baumé's treatise on chemistry, it seemed as if centuries separated the two books. Lavoisier's can be read with complete understanding by any modern chemist, Baumé's is a confused jumble of phlogistic dogma, mystical sulfur, oil and salt, and the four elements of Aristotle, totally incomprehensible to moderns.

In one supreme effort, Lavoisier had cast off the shackles of the past, broken with tradition, demolished phlogiston, and set forth before the eyes of the world a new science—chemistry—complete in detail, in organization, in delineation, in scope, in vision. What he did he did almost alone, unsupported, unencouraged, opposed at every step by tradition, authority and men of science. When it looked as if the credit for this great new theory would fall into the laps of the so-called "French Chemists," Lavoisier was wholly justified in claiming that "this theory is not the theory of the French Chemists; it is *my* theory."

[13] McKie, Douglas, *Antoine Lavoisier*, p. 273. Philadelphia: Lippincott, 1934.

It was his theory in all its parts and in all its fullness even though none of the facts upon which it was based was original with him. He did as Newton did, fitted the isolated facts of others into a new harmonious design with each part lending support to the other.

If every accusation charged against Lavoisier were true, it would make no difference. His fame rests not on the originality of his experiments but on the way they were put together. We admire the edifice now for its beauty and utility; we are no longer concerned with the question of who quarried the rock. We admire Lavoisier for the sheer genius he showed, for the tremendous energy he displayed, for the monumental conclusions he obtained, for the magnificent structure he built.

Both Priestley and Cavendish had the opportunity to do with their own discoveries what Lavoisier did with them. Priestley, in fact, had a better opportunity, for he knew far more about gases than Lavoisier would ever know. Both Priestley and Cavendish were justified in their complaints against Lavoisier's use of their facts. Yet, the world must be thankful that Lavoisier had both the ability and the courage to make use of them.

Lord Brougham is one of the harshest critics of Lavoisier's unethical conduct in science but he concludes that "After all the deductions which can fairly be made from his merits, these stand high indeed, and leave his renown as brilliant as that of anyone who ever cultivated physical science . . . [His researches] are sufficient to place him among the first, perhaps to make him be regarded as the first performer in chemical science, the principal founder of that magnificent fabric which now fills so ample a space in the eye of every student of nature."

Lavoisier's book was finished and off the press in 1789. What kind of reception would it have from the conservatives of phlogiston? Priestley would, of course, never endorse it; Cavendish, forgetful of chemistry, had turned to physics and was busy weighing the world; he would be unconcerned. Baumé, Sage, Monnet and others would fight it vigorously in France. But for all of these, there was no stemming of the tide

which had begun to set in when Lavoisier gained his first three disciples.

In Germany, according to Robison, the new theory was received with great hesitation and doubt and even with aversion, an aversion "chiefly owing to the character of the nation from whence [it] came. The Germans, who had been accustomed to consider themselves as the chemical teachers of Europe could not bear to hear the opinions of their master, Stahl, treated with contempt; . . . But, what provoked them most was the pitiful triumphs of victory in which the 'French Chemists' indulged themselves."

This reference is to a story that Madame Lavoisier, garbed in the robes of an ancient priestess, with the spirit of Stahl present as devil's advocate, and with oxygen accusing phlogiston, burned Stahl's great *Chemiae Dogmatica et Experimentalis Fundamenta* on an altar of progress. Robison adds, "If Newton or Black had so exulted over Des Cartes and Meyer, their countrymen would have concluded that they were out of their senses. But at Paris everything becomes a mode and must be fête."

It is true that one can scarcely imagine staid Englishmen acting out such a comedy. It is also true that neither Newton nor Black had to battle against the whole weight of ancient tradition. Newton put the finishing touch upon a theory ready to fall into place. There was no previous theory to overcome. To compare the argument between Black and Meyer over fixed air with the battle to dethrone phlogiston is obviously absurd. And what about the Germans who were so offended? The report is that they retaliated by burning Lavoisier in effigy in Berlin. If the affair did take place it was a prank and not intended as an insult to German scientists. It is difficult to imagine the reserved Lavoisier participating in such a burlesque, but if he did, it gives unmistakable evidence that he had a sense of humor.

In spite of his disgust at the way the Horsemen of France were thrusting the new theory down the throat of the scientific world, the grand old man of Scotch chemistry, Joseph Black, was one of the first to accept its tenets. Says Robison, "No man

had a higher opinion of the genius, penetration and sagacity of Mr. Lavoisier than Dr. Black; and I have often heard him lament the loss which science sustained by his death. He admired particularly Lavoisier's quick sight of the importance of Mr. Cavendish's discovery of the composition of water, and his employing it immediately . . . even to extend his doctrine far beyond the first conception of it. Dr. Black adopted all of Lavoisier's doctrines, but he did not like the officious (as he called it) interference of some of his coadjuters; and he said that Berthollet was the only one of them in whose judgment and caution he had full confidence."

Upon learning, in 1790, that Black had adopted his theory, Lavoisier wrote the old master a flattering letter, as was the custom at that time in France. "I note," he wrote, "with inexpressible joy that you attach some merit to the ideas which I have been the first to present against the doctrine of phlogiston. . . . Your approbation, sir, removes my disquietude and gives me new courage. I shall not be satisfied until circumstances permit me to bring to you the testimony of my admiration. I count myself as one of your followers." To this flattering letter Dr. Black replied with "a very plain, candid and unadorned letter . . . expressing his acquiescence in his system."

This letter which Robison describes as "plain, candid and unadorned" nevertheless went the whole enthusiastic way in support of the new theory. Wrote Black (in part): "The many skillful experiments which you have made in the great way, have been prosecuted through all their changing phenomena with such assiduous care, and such scrupulous attention, that nothing can be more satisfactory than the proof to which they have conducted you. The system which you have founded upon your facts is . . . so simple and easily intelligible, that it must daily obtain increasing approbation; and cannot fail to be adopted by a great many chemists. I am . . . convinced that your doctrine is infinitely better founded than the old theory, and in this respect, cannot suffer by a comparison with it." Quite a flattering letter from a Scotsman!

Again Lavoisier wrote "praising in highest terms the elegance of the style, the profoundness of the philosophy and

begged leave to insert the letter in the *Annales de Chymie*. Dr. Black, "disgusted with what he now conceived to be artful flattery, refused to grant the request." But "his letter appeared . . . before his answer could reach Paris."

Robison adds, "This wheedling in order to screw out of Dr. Black an acquiescence, on which he put a high value for the influence which it would have on the minds of others, was surely unworthy of Lavoisier. Dr. Black was not only disgusted with the flattery but seriously offended with its insincerity [from] a man whose publications never expressed the smallest deference for his opinions. For by this time Dr. Black had read Lavoisier's *Elements of Chemistry* and various dissertations by him and Mr. De Laplace. . . . His name is not mentioned even in the dissertations on the measures of heat. Nor is he named where the characters and properties of fixed air . . . are treated. . . . But still, notwithstanding the contempt which he expressed for the folly of a man who had tried, by fulsome and insincere flattery to obtain what he had given him unasked by teaching all of his doctrines, Dr. Black considered the death of Lavoisier as a great loss to science." Truly Dr. Black was a wise and a magnanimous man! He placed scientific truth far above personal feelings.

In France, Monge soon joined the Horsemen. In Montpellier, young Jean-Antoine Chaptal newly appointed professor of chemistry adopted the new theory in his first lecture. "At the time I commenced to teach chemistry," he wrote, "the new doctrine had not been established; the old had begun to crumble. The discovery of gas, the decomposition of air, the theory of oxidation of metals, set forth in the memoirs of Lavoisier . . . exhibited to us the dawn of a new day in chemistry. I took pleasure in the explanation of new facts, and it was upon the new theory that I based my first lecture."

Lavoisier wrote to him, "To see you adopt the principles which I first announced is to me a real joy. The conquest of yourself, De Morveau, and of a small number of chemists scattered through Europe is all that I had the ambition of accomplishing, and the success surpasses my hopes. I receive from all sides letters announcing new proselytes, and I see now that

only aged persons who have no longer the courage to begin again their studies, or who can no longer turn their imagination to a new order of things, still hold to the doctrine of phlogiston. All young people adopt the new doctrines, and from this I conclude that the revolution in chemistry is complete."

Chaptal lived through the Reign of Terror to become Comte de Chanteloup, Minister of the Interior under Napoleon. But when he crossed the Emperor's path of dalliance in seeking the favor of Mlle. Burgoin of the *Comédie Française,* he suddenly found himself offered an ambassadorship at a far-off court. This honor he refused. Eva V. Armstrong and Hiram S. Lukens, in writing about Chaptal say, "One evening when Chaptal was closeted with the Emperor discussing affairs of state, the arrival of Mlle. Burgoin was announced. Napoleon begged her to wait for him. It was a surprise which he had carefully arranged. Chaptal rose, placed his papers in his portfolio, and left abruptly. The same night he wrote a letter of resignation, requesting permission to retire to Montpellier and devote himself wholly to the pursuits of science."[14] The experimental work of Chaptal in applying chemistry to industry was brilliant.

In far-off America, young and full of enthusiasm, the new theory took hold rapidly. James Woodhouse, pioneer American chemist, espoused the cause "endeavoring with all his experimental skill to counteract . . . the phlogistic notions of Priestley." Said the late Edgar F. Smith, "There seems not the slightest doubt but that Mitchill, Coxe, Woodhouse, Hare, Silliman and other early American chemists assiduously studied the pages of Lavoisier's chemistry."[15]

The book was translated into English and German and went through many editions. The excellent text of Fourcroy, following that of his master, had even greater effect in converting sceptics, though many of the conversions came after the death of the master. In the third edition of this book published two years after the death of Lavoisier, Fourcroy speaks, not of the

[14] Armstrong, Eva V., and Lukens, Hiram S., "Jean Antoine Chaptal, Comte de Chanteloupe," *Journal of Chemical Education,* vol. 13, p. 257, 1936.

[15] Smith, Edgar Fahs, *Chemistry in America,* p. 12. New York: D. Appleton and Co., 1914.

theory of the "French Chemists," but of the theory of Lavoisier. He speaks of "Its simplicity, its systematic progress, its perspicuity, and ease with which it is applicable to all the phenomena of chemistry. . . ." And again, "The elegant theory of M. Lavoisier in the years 1776 and 1777 that explained all the phenomena of combustion. . . ."

It was with great pleasure that Berthollet read a letter from Kirwan in 1792. Good friend of Priestley, writer of the famous *Essay on Phlogiston* (1788), which book had been translated into French by Mme. Lavoisier and answered page by page, chapter by chapter by the Four Horsemen, Kirwan had capitulated to Lavoisier's theory. "At last," he wrote, "I lay down my arms and abandon the cause of phlogiston. . . . Without decisive experiments we cannot form a system in opposition to positive facts. I shall compose a refutation to my own essay." Magnanimous surrender!

It is probable that Benjamin Franklin never read Lavoisier's book. A copy, together with a letter, was sent him in February 1790; Frankin died two months later. In the letter Lavoisier speaks modestly of his own aims and achievements.

"In all work on chemistry," he wrote, "which have been published since Stahl, the authors have begun by laying down an hypothesis and afterwards have attempted to show that with this given principle all the phenomena of chemistry might be accounted for tolerably well.

"I believed, and a great number of scholars of today agreed with me, that the hypothesis advanced by Stahl, and since modified, is erroneous, that phlogiston in the sense that Stahl understood the word does not exist, and it was principally to develop my ideas on this subject that I undertook the work which I have the honor to send you. . . .

"The French scholars are divided at this moment between the old and the new doctrine. I have on my side M. de Morveau, M. Berthollet, M. de Fourcroy, M. de Laplace, M. Monge, and in general the physicians of the Academy. The scholars of London and England have unconsciously abandoned the doctrines of Stahl, but the German chemists adhere to it. This then is the revolution which has occurred since your departure from Eu-

rope; I look upon this revolution as well advanced and it will be complete if you will stand with us."

This was indeed the revolution which had taken place in chemistry and which had reached its magnificent culmination just as life was passing from the feeble frame of the aged American who had played such a crucial rôle in another great revolution.

"The importance of the end in view prompted me to undertake this work which seemed to me destined to bring about a revolution in chemistry." This was what Lavoisier had written in 1773. Then, for sixteen years he had fought his way step by step, often slipping back, through a maze of contradiction, hostility, jealousy, disappointment; at times doubtful, embarrassed, harassed; at other times happy, confident, aggressive. Never wavering far from his early conviction, he had come through the fog to stand on the highest pinnacle of scientific fame. A more timorous man would have given up in face of opposition; a less sagacious man would have fallen victim to the snare of his own experiments; a less imaginative man would never have lived such a dream; a less persistent man could never have done the tremendous amount of work necessary to bring the evidence together. Only a Lavoisier had all of these qualities properly coordinated to win a magnificent victory.

Before Lavoisier, stalked mysticism, confusion, and contradiction; after Lavoisier, came system, order, and progress. Yet, the future was built out of the past, on the past, by a mere revaluation of old phenomena. The greatness of the new chemistry lay not in its facts. These were old. It lay rather in its spirit of independence and method. These were new and inspired.

Beginning of the French Revolution

WHILE the revolution in chemistry was being fought, the financial affairs of France were going from bad to worse. Turgot had been forced out of office; Necker, with all of his financial necromancy, had failed; he dared not attempt the overthrow of ancient privilege. The American war of independence had cost France two billion livres. After borrowing to the limit, Necker had published his famous *Compte rendu,* a document purporting to show a balanced budget based on peacetime operations. Instead of restoring confidence, it provided the parlements with an excuse to demand fiscal reform. In 1781, Necker resigned, aggrieved because, as a Protestant, he was denied the title of minister.

Joly de Fleury, his successor, lacked the confidence of the financiers and was forced to turn to new taxes. This aroused the ire of the parlements and Fleury retreated to the worst evil of all, creating and selling new offices. Intrigue forced him from office in 1783.

Lefebvre d'Ormesson followed Fleury. In sheer desperation, he resorted to borrowing secretly from the Discount Bank. Soon the bank was forced to suspend payments and the public learned what had been going on. Lavoisier was on the governing board of the bank; it was D'Ormesson who appointed him to the administrative committee of the tax farm. It is easy to conclude that there was a connection between these two facts. Was D'Ormesson rewarding a favor done, or buying silence? There is no evidence that it was either. The very fact that there is some question concerning Lavoisier's actual service on the administrative committee might also lead to the conclusion that

he was opposed to the secret loans and refused to be bought. D'Ormesson's term of office lasted just eight months.

Then came the frivolous Calonne. With the nation again at peace, Calonne reasoned that the way to prosperity lay in spending. He borrowed from all who would loan and established an elaborate system of public works. The farm advanced him two hundred and fifty million. It was but a drop. Realizing the necessity for profound revision in the tax structure, revision which would make the tax burden more equitable, but realizing also that the parlements would probably not approve such proposals, Calonne recommended to Louis the assembling of the Notables of France. If this body approved, the parlements might be won over.

The king wavered but finally bowed to what he regarded as the inevitable. In February 1787 the Notables assembled at Versailles. Calonne had overlooked one important thing: he had failed to prepare a constructive program of tax reform. Had he done so, and had the Notables cooperated instead of sitting obstinately by, France might have been saved a bloody revolution. But it was not to be. Out of office went Calonne after he had secured the dismissal of the queen's favorite, Breteuil.

In stepped the handsome, courteous, Loménie de Brienne, Archbishop of Toulouse, member of the Notables, to finish the job of coercing that body into action. It was too late. The Notables went home after having done little or nothing; but they did approve one constructive act, the reestablishment of the provincial assemblies first authorized by Turgot and recommended to the Notables by Calonne on the advice of Du Pont. In doing nothing, however, the Notables had done something which would alter the whole structure of France. The only way now left to secure the necessary reforms was through the States-General, the legislative body of France which had been suppressed by absolute monarchs since 1614.

The meeting of the Notables had, as La Fayette said, "set people to thinking about public affairs." Common France was indeed beginning to catch the idea that in national bankruptcy lay the way to political reform. Marie Antoinette was dubbed

Madame Deficit and advised to stay off the streets of Paris if she would not hear hisses.

First to organize under the edict restoring the provincial assemblies was the province of Orléans. In this province lay Lavoisier's country estate of Fréchines. First among the organizers was Lavoisier, himself. He was appointed to represent the district of Romorantin. We see the scientist in a new rôle, that of a provincial statesman. In this rôle we see an unmistakable picture of his liberal leanings, progressive ideals and humanitarian motives.

Lavoisier possessed a patent of nobility. Where was he to be found—sitting among the nobles? No, he represented the Third Estate, his fellow farmers and townsmen of Romorantin. With the commoners he stood uncovered in the presence of the nobles; with the commoners he marched to church on Sunday, preceded by soldiers and the city band. Among the twenty-four commoners there was only one whose life's work would live forever.

The formal opening of the Assembly was an occasion for speeches and ritual. Representing the Third Estate on the reception committee was Lavoisier. With the Abbé de la Géard, the Duke of Luxembourg and the mayor of Orléans, he stood at the head of the staircase to receive the king's representative. With the commoners, he uncovered while listening to the king's message.

The principal session opened in October 1787. Lavoisier, as might be anticipated, was chosen secretary of the session. He was to be seen in the eyes of a contemporary as "the one who does all things . . . whose name is constantly heard."

As a member of the Bureau of Public Good, he found wide latitude for his liberal ideas. First, he plunged into an attack on the vicious tax of the "twentieth," a tax which fell heavily on the small land owner and from which most nobles were exempt by connivance. With the Abbé Sieyès and Count Rochambeau, hero of the American war, he worked for the substitution of a more equitable tax.

Next we find him fighting the cause of the peasant in a valiant but unsuccessful attempt to abolish the corvée from the

province. The privileged classes could, of course, be called on to do no servile labor nor did they support highway building with funds. This inequitable tax, argued Lavoisier, was inflicted on the peasant without even a royal law. It was of neither Roman nor feudal origin. Nowhere had such a law ever been written into the statutes of France. "The law of 1776," he added, "is the first law in which the corvée is mentioned, and that mention is to abolish it." Lavoisier had never forgotten those lessons in physiocratic economics learned at the feet of Turgot, in his earlier days.

The next of Lavoisier's proposals was a century ahead of its time. It was nothing less than a project of state old age and unemployment insurance. In an elaborate introduction typical of the times he wrote: "Man at birth is powerless to satisfy his needs. He must depend on others and subsists only through their care. Little by little, he gains maturity and power. Then comes the time when he bears his own weight and that of others. This is the most brilliant moment of life. In old age, strength fails and he is once more dependent on others. Happy is he who, surrounded by a grateful and tender family, receives in his last years the same aid he bestowed upon others in his prime. . . ." Then he went on to discuss premiums, mortality tables and details of operation. Unfortunately, this novel project never came to fruition, but the views of Lavoisier on social insurance were, to say the least, unusual for a man of his class and rank.

Again, Lavoisier was proposing a branch discount bank for the province. As a governor of the Discount Bank of Paris established by Turgot, he realized the crying need for the extension of credit to supplement the inadequate currency of the nation. "Commerce," he said, "is restrained and limited by lack of capital." He also proposed that the province cut down its tax-collecting expense by buying back from the provincial "farmers of the taxes" their remunerative contracts and doing the collecting itself. Here was Lavoisier, himself a "farmer of the taxes," proposing to abolish similar posts in the province. Would he have been equally quick to propose the abolition of the *ferme générale* which had brought him, in a large measure, his wealth? His whole attitude toward such questions and his

conduct in the farm indicates that his answer would have been "yes" provided such collections could be placed in the hands of agents responsible to the *people,* not the crown.

In agricultural problems, he drew on results of his experiments at Fréchines. He offered his services in the preparation of a geographical and geological map of the province and proposed a collection of typical minerals.

In all of his work in the Assembly, he did nothing ostentatiously, nothing officiously. He played the rôle of a progressive member working for the welfare of his constituents and not for his own glory. He made no attempt to publish his many papers; they lay in the archives gathering dust till unearthed many generations later. Had his work in this provincial assembly, forerunner of the National Assembly, been given due publicity, Lavoisier would have ranked among contemporaries as a political thinker and economist of no mean merit. But the doings of these significant provincial assemblies were so far overshadowed by the national tumult soon to follow that they left little imprint on the pages of history.

In Paris, parlement was openly defying the king. It was demanding a financial accounting, the calling of the States-General, and was refusing to levy taxes on privileged groups. For its mutiny the king banished it to Troyes. But it would not stay there. All of Paris rose up demanding its return. Back it came more defiant than ever. Encouraged by the Duc d'Orléans, it refused to register the king's edict for a loan of four hundred million livres. For his part in the affair the Duc was banished to his château at Villers-Cotterets. Martial law and civil war were imminent. It was the States-General or anarchy. Finally, on August 8, 1788, wavering Louis agreed to call the States-General together to meet May 1, 1789. Almost in the same breath, he dismissed the futile Brienne and recalled faithful Necker. Necker was back in the saddle more boastful than ever. Up went the stock market when the Genevan spectacularly placed half of his private fortune at the disposal of the government, a half he never saw again. The Discount Bank resumed business once more. Even popular Necker, however, with his cohorts, could not save France now. It was too late.

"Ah," explained Necker, "if they had only given me the fifteen months of the Archbishop Brienne!" But Necker had not the courage to do what was needed. Like Calonne, he had no plan.

Since 1614 there had been no meeting of the States-General. How should it be organized and constituted? "According to the forms of 1614," replied the Notables. Should the Third Estate have representation equal to or double that of the other orders; should the three estates deliberate together as one house or separately as in former times? These were the two questions of the moment. The stirring pamphlet of the Abbé Sieyès struck the key-note: "What is the Third Estate? Everything. What has it been in the political order? Nothing. What does it demand? To become something."

Lavoisier shared the popular enthusiasm of the day. Like others of his liberal caste, he felt that the States-General would bring greater justice and equality, level off the oppressive taxes, and effect a constitutional monarchy. He wrote to the executive committee of the Orléans assembly of which he was a member, "The nation is enlightened; it knows that it owes its good fortune to the people at large. If exceptions are made in taxes they must be made in favor of the poor . . . and not in favor of the rich."

In a memoir to Necker, Lavoisier proposed that the deputies to the States-General be chosen by the provincial assemblies. He demanded a double representation for the Third Estate, a representation which would "give justice" to the common people. He demanded the elimination of *lettres-de-cachet*, freedom of the press and regular future meetings of the States-General. He proposed that the Assembly draw up a new national constitution, impose taxes, examine laws and promote reforms in them. He proposed, finally, that the name be changed from States-General to National Assembly.

In February 1789, Lavoisier was off for Blois, there to act with a committee of nobles in choosing deputies and to edit for the committee a pamphlet of instructions for the chosen deputies. Why was Lavoisier working with the nobles this time instead of with the commoners as before? Because his experience in the provincial assembly had shown him that only through

the appointment of liberal nobles could such an assembly hope to make progress. Though the Third Estate was to have representation equal in number to the other two estates together, the balance of power would still lie with the united nobles and clergy. Only by breaking this united front was real progress possible. The pamphlet of instructions edited by Lavoisier contains a clear exposition of his liberal views. "The goal of all social institutions," he wrote, "is to bring happiness to those living under them." There followed a statement of Lavoisier's beliefs: the just rights of all men, removal of the right to exile men without due process of law, freedom of the press, abolition of arbitrary police powers, taxation by consent of the taxed, and proportionate to wealth, removal of the corvée and the substitution of a highway tax, and finally, the establishment of a constitutional monarchy to replace the tyranny of the Ancien Régime.

Probably Lavoisier wanted to be a deputy to the States-General. His experience in the provincial assembly, his work on its executive committee and his editorship of the instructions to deputies all entitled him to such a place. He was deeply, honestly interested in reform. He would have been an ideal liberal deputy. But, once more fate was against him. Gossip of the times had it that he failed of election because he was a member of the farm. These farmers were still in ill-repute. Grimaux maintains that it was because his patent of nobility was too new. Only nobles of long standing could be chosen. At all events, he was chosen an alternate deputy but never sat in the States-General or the National Assembly.

It is unfortunate that we cannot see Lavoisier in the States-General. Where would he have stood? With the recalcitrant nobles refusing to unite with the commoners, standing on ancient privileges, blocking the way to all reform? That is not Lavoisier! We see him, rather, fighting side by side with La Fayette, Clermont-Tonnerre, Duc de la Rochefoucauld, and the De Lameths for a democratic united National Assembly where lord and peasant would rub elbows in making common cause for their country.

The States-General met in full ceremony; the king had permitted double representation for the Third Estate but had refused to allow the three estates to meet together. The Third Estate, recognizing its own futility under such a plan, insisted on a united assembly. Only with the help of the sympathetic lower clergy and liberal nobles could any real reforms be instituted. For a month it threatened, begged, coerced the other orders but to no avail.

The Abbé Sieyès failed of election in his order but he was elected to the Third Estate. Now he demanded a clean cutting of the knotted cord. Let the clergy and the nobles do whatever they will, he said. The Third Estate would constitute itself a National Assembly and proceed to the business of the nation. Hereafter it would make the laws of France. Even Necker was alarmed at this suggestion of mutiny. It was the first step to revolution.

Now the Assembly proceeds to elect mild philosopher-astronomer Bailly as its president. Bring on the troops, rout out the mutineers, shout the partisans of privilege. The king compromises by having the doors of the assembly hall locked under the pretext of repairs to be made. In the soaking morning rain of June 20, the commoners rush excitedly about looking for a place to meet. "To the tennis courts," suggests good Dr. Guillotin. To the unused tennis courts the commoners move, and there they take a mighty oath. Neither coercion nor bayonet will disperse them till France has received a constitution. This was real revolt. Dutifully, but half-heartedly they cheer the king, these mutineers.

The time has come for the king to take a firm step. Three days later he assembles the whole of the States-General, makes a conciliatory speech and bids its orders go their several ways to deliberate. It is too late; the commoners will not budge from their places. They are organized at last. Mirabeau shouts, "We are here by the will of the people and nothing but the bayonet will drive us hence."

"Ten thousand people," says Young, "have been all this day in the Palais-Royal." At Versailles the crowd demands to see and hear its hero, Necker. The French guards join the popu-

lace. "We will defend our king," they cry, "but we will not cut the throats of our fellow citizens." So great is the power of such psychology that most of the nobles and bishops find it expedient to change their minds and join the Third Estate. With them goes the Duc d'Orléans. The Third Estate has become the National Assembly of France. "The family," says Bailly, "is now complete." The king could do no more than give it his blessing.

He blesses it, however, with his usual mental reservations. Already he is beginning to regret his action. Necker has given him bad advice. The queen and her supporters urge military force to blast this treasonable assemblage out of existence. Necker must go. He is sent off in the dead of night and Breteuil, pet of Marie Antoinette, gets his post. Old Maréchal de Broglie and Foulon get posts in the ministry too. Troops are secretly thrown between Paris and Versailles.

On the following day Paris wakes to learn of the treachery. Foulon, who was rumored to have said, "Let the people eat grass if they are hungry," now a minister of the government! Necker dismissed, Swiss and German mercenaries guarding Versailles! Wild tumult swings through the courts of the Palais-Royal.

Through the streets swarms the mob led by the busts of Necker and Orléans held aloft where all can see. Shots are fired by the mercenaries; one of the mob drops dead. The Opéra is invaded and the curtain falls in the middle of an aria. Custom houses go up in smoke; Breteuil's palace is sacked.

There is a grim seriousness about these Parisians as they go about collecting arms and munitions. Armorers and gunsmiths work all night. Ornaments are melted into pikes, wagon springs into spears.

Lavoisier is deeply worried. Entrusted to his care in the Arsenal are many kegs of valuable powder, enough to blow up Paris. The Arsenal is undefended. Much as he favors reform, he deplores force of arms and bloody revolution. The powder should be in a safer place. Perhaps he is ordered to move it to the Bastille around the corner from the Arsenal. But before the job is completed, the mob arrives. They demand powder and flints, and powder and flints they get. "A distracted 'Peruke-

maker with two fiery torches' is for burning 'the saltpetres of the Arsenal,' had not a woman run screaming; had not a patriot with some tincture of natural philosophy instantly struck the wind out of him (butt of musket on pit of stomach), overturned barrels, and stayed the devouring element," so wrote Carlyle. In all probability, little powder was ever moved to the Bastille. But Lavoisier will hear of this episode again, will hear of it from the lips of Dr. Marat.

Another mob storms the Invalides and helps itself to the store of antique firearms. Now let the mercenaries attack Paris if they dare! Paris is armed with pike, axe, spear, gun and stave. It is the eve of July 14, 1789.

Someone suggests that there are arms and munitions in the Bastille. Off goes the crowd to see. Some French Guards join the parade and roll their cannon toward the fortress. Thus began the accident of Bastille Day. De Launey, aged governor of the Bastille, has but thirty-two Swiss guards and eighty-two invalided French soldiers. It is rumored that he threatens to blow the Bastille up with powder sent from the Arsenal. Instead, he temporizes, then orders the raised drawbridge dropped. With the courtyard filled, the drawbridge is raised again. Shots are fired and the crowd surges forward. De Launey agrees to surrender if he and his men are not harmed. But who could answer for a mob? De Launey is rushed out into the streets to face his accusers. In the streets, too, is old Clouet, colleague of Lavoisier on the powder commission. He is in uniform and resembles De Launey. The mob attacks him by mistake. He barely escapes with his life, and, carried into the Arsenal, is more dead than alive. De Launey fares even worse. He is butchered long before the city hall is reached; his staring head rides a pike the rest of the way; his unhearing ears heed not the hissing and the tumult of victory. For all of its efforts the crowd found little of arms or powder in the Bastille.

What did Lavoisier do during the eventful day of July 14? What could he do? He was not a leader of mobs, not a demagogue. He sympathized with the motives of the Revolution but intelligence placed him beyond the sway of mob psychology.

From his apartment in the Arsenal, he must have seen and heard all.

Louis is truly alarmed now. He even thinks of becoming a liberal himself. Under the wise tutelage of Rochefoucauld, close friend of Lavoisier, he becomes for a brief moment a leader of reform and swears to support the National Assembly. In Paris the crowd elects Bailly as its mayor by popular acclaim. La Fayette is chosen commander of the National Guard, the citizen soldiery of Paris. The king comes to Paris to approve all that has been done. Necker, playing an enforced game of "in and out" is in once more, in to see his popularity fade rapidly before the onslaughts of the National Assembly. The emigrés are leaving Paris; old Foulon is butchered. His gaping mouth is stuffed with hay that he may enjoy the diet he once recommended for starving Paris. La Fayette and Bailly pray for rainy days, for only then is the Parisian mob quiet.

It was one of these trouble-seeking mobs which nearly cost Lavoisier his life in the summer of 1789. The supposed removal of powder to the Bastille on July 13 had left an ugly feeling among the people. Shipments of powder around the country had been intercepted by revolutionists and converted to their own use.

In August a barge load of industrial powder, *poudre de traite,* was shipped from Metz destined for the store houses of Rouen and Nantes. At Château Thierry the barge was seized by self-appointed vigilantes and sent on to Paris. At the port of St. Paul, near the Arsenal, the barge was unloaded. Lavoisier and his colleagues were perplexed. It was not musket powder; there was no storage space for it in the Arsenal. It was decided that this lost shipment should be sent on to Essonnes for storage and an equal amount of musket powder be returned from Essonnes to the Paris Arsenal. But no munitions of any sort could leave Paris without the written consent of La Fayette. Lavoisier hastened to the city hall. La Fayette was absent. His adjutant, the Marquis de La Salle, was present and promptly signed the order; it was merely a routine matter.

At the Port of St. Paul, however, it was not a routine matter. Loiterers on the river bank saw this powder, which patriots

had "saved from the enemies of France," going back into the barge once more. Suspicions were aroused. *Poudre de traite* was easily confused with *traitre.* "Traitor," went the cry along the river front. "Send for La Fayette, our leader," shouted others. A delegation was sent to see La Fayette. He knew nothing of the matter—nor did he bother to ask La Salle. He had signed no order. But now he did sign one—ordering the barge to be unloaded immediately and the powder placed in the Arsenal. Once more workers began removing kegs in this comedy of errors. There were angry mutterings: "Hang Lavoisier the traitor! String up the whole powder commission! They would rob Paris of powder and flints." La Fayette's summary order had placed Lavoisier in a most embarrassing and suspicious position.

On the following day Lavoisier appeared before the local commune to explain the tangled situation. Two deputies were sent to examine the powder. They found it to be exactly what it was represented to be, industrial powder, and the powder commission was given a clean bill of health. Once more the kegs began rolling onto the barge. The crowd, however, was far from satisfied; it had been tricked by someone and someone must pay. Milling around the gates of the Arsenal, it demanded the arrest of Lavoisier and Faucheux. Clouet, still suffering from his wounds of July 14, escaped this ignominious trip to the city hall. With the mob surging at his heels threatening to hang him from every lamppost, Lavoisier made his way to the city hall once more. At each step the crowd grew larger till it completely filled the Place de Grève.

At the city hall Lavoisier had no difficulty in producing the order signed by La Salle. Having lost one scapegoat, the crowd must have another; its fury turned upon La Salle. Streaming through the building it sought the unfortunate adjutant in every corner. But the miserable Marquis was hidden in the bell-tower beyond reach of his angry assailants. In vain did La Fayette attempt to calm the angry horde. Finally, in desperation, he ordered the arrest of his own adjutant. Bailly, returning late at night from the meeting of the Assembly at Versailles was informed of the riot and, deeply concerned for Lavoisier's safety,

hastened to the city hall. There he found that La Fayette had finally reestablished order and Lavoisier was safe.

On the following day the controversial load of powder left Paris for Essonnes. Four days later the barge returned with a load of musket powder for the Arsenal. The ugly feelings of the public were somewhat assuaged. The whole affair left, however, a mark of suspicion on Lavoisier, a mark which would never be forgotten.

Following the fall of the Bastille came the fall of bastilles all over France. In the provinces, peasants and townspeople experienced the Great Fear. Rumors flew thick and fast that an enemy, perhaps a royalist mob, was marching on them. Grasping pitchforks and shovels the peasants marched forth to meet the "bandits." When no bandits came, they turned, in vengeful mood, to attack the local lords. Manorial rolls, on which the feudal dues were inscribed, were burned, châteaux sacked. Fréchines escaped this fate because of the good will created by Lavoisier among his neighbors. But in 1793 his château was entered by a group of men, the tax-rolls and other records removed and burned.

By August, the Revolution had moved so far and so fast that even the stubborn privileged class realized that the end of their privileges was near. On the evening of August 4, 1789, Vicomte de Noailles, a relative of La Fayette, gave an impassioned speech in the National Assembly demanding the abolition of feudal rights. Since he had no land he had nothing to lose. There followed a night of hysteria in which noble and clergy vied with each other in giving up ancient privileges. All Frenchmen were made "equal" and Louis XVI hailed as "the restorer of French liberty." The Assembly then turned to the task of drawing up the famous Declaration of the Rights of Man.

Weeks passed; the Assembly was at work on the new constitution but the king had not yet ratified the decrees of August 4. In September, the Regiment of Flanders arrived at Versailles and was lavishly banqueted by the royal bodyguard. Toasts were drunk to the king, tricolor cockades were torn off and the

Assembly denounced—at least these were the rumors which reached Paris. Added to this was the high cost of bread in Paris.

On the morning of October 5, a crowd of women, some of them men dressed in the garb of women, appeared before the city hall demanding bread. There was none. Maillard of Bastille fame shouted, "To Versailles," and off went the crowd of "fishwomen" augmented by thousands along the way. Trailing far behind came La Fayette and the National Guards.

The Assembly appointed a delegation to go with the women to the king. Louis, willing to please, promised bread. During the rainy night, the women camped in the courtyard of Versailles. Toward morning a small group of them tried to force their way into the queen's apartment; two bodyguards blocked the way and were killed; the queen escaped.

In the morning La Fayette and the royal family were cheered but the crowd insisted that the king and queen accompany it back to Paris. Thus did the "baker, and the baker's wife, and the baker's little boy" return to Paris and to virtual captivity in the Tuileries. They would never see Versailles again.

All over Paris political clubs were forming. Parent of most of these was the Breton Club which included in its membership many liberal young lawyers and nobles. Barnave, the De Lameths, Mirabeau, Robespierre, Fouquier-Tinville, Du Pont, Condorcet, Lavoisier, La Fayette and many more of similar leanings found their way to its meetings. In its meetings, too, were laid the foundations for the abdication of feudal rights and from it stemmed most of the important revolutionary clubs. From those on the left, believers in a republic, came the Cordelier's Club, led by Danton and Desmoulins. From the right, believers in constitutional monarchy, came the Club of '89, later the Feuillant's Club. From the center came the all-powerful Jacobins with Robespierre the guiding star.

With the Club of '89 went La Fayette, Bailly, Monge, Vandermond, Brissot, Abbé Sieyès, Du Pont, Roederer, Mirabeau, Talleyrand, Lavoisier and many more of their stamp. As usual, Lavoisier was to be found in the secretary's chair. With such men among its members the '89 enjoyed great popularity for a

brief moment. When it held its banquets in the Palais-Royal, the crowd surged about outside cheering its heroes and demanding a sight of Bailly, La Fayette, Mirabeau, Sieyès at the window. But the '89 was not in keeping with times which demanded demagogues and excitement. Its purpose, "to consider questions of general interest and political metaphysics without regard to party or creed," was far too intellectual for the *sans-culottes* of Paris. Its popularity soon began to wane. Lavoisier presented few papers before the club. His memoir on paper money, the assignats, issued against the confiscated property of the Church, carried a clear warning of the dangers of such a policy if carried too far. His predictions were fulfilled a few years later.

When the '89 began to lose its popularity, many of its members deserted it with alacrity. The club which had started out in 1789 with most of the brilliant founders of constitutional monarchy ended its career a few years later in ignominy. To the last, however, Lavoisier stuck to the '89 which represented his scientific judgment and his political opinion. In his secretary's book are recorded no meetings, no memoirs for the year of 1792.

Though Lavoisier failed of election to the States-General, he was elected to the newly organized Paris assembly or commune in September 1789, as a deputy from the district of Culture St. Catharine. He sat with such academicians as Condorcet, Cousin, Thouin, Broussonnet, De Machy, and with Danton.

More important than Lavoisier's work in politics at this period was his work in finance. As a governor of the Discount Bank of Paris, he had suffered many uneasy moments during these panicky years. This bank had proved a convenient "pot of gold" for several ministers. Brienne, as well as D'Ormesson, had used it in emergency to cover governmental deficits and had thus forced it to suspend payments. With the return of Necker and the formulation of the Declaration of Rights, however, there was a surge of confidence and patriotism. Citizens rushed forward with gifts to the treasury. Women stripped off their jewels; the Duc de Charost-Béthune gave a hundred

thousand livres; a prominent Parisian courtesan gave twelve thousand; the king gave the royal gold plate, the Assembly gave their silver shoe buckles. Lavoisier gave thirty thousand livres.

The Discount Bank was saved, and its governors were publicly thanked by the Assembly for their patriotic actions in using their personal fortunes to sustain the bank through its trying days. Such patriotism, however, would count for nothing at a later date.

When Necker proposed converting the Discount Bank into a National Bank (as was later done by Napoleon), Lavoisier was called before the Assembly to present a report on the financial situation of the bank. His report showed that the nation owed the bank seventy millions. Mirabeau objected to the proposed change. "If," he said, "the state is to guarantee the notes, why not let the state issue them?"

Mirabeau's plan prevailed; the government issued assignats, paper notes, secured by confiscated Church lands. Though Mirabeau's plan was essentially sound, politics, war, counterfeiting and, lastly, the printing of too many assignats combined to depreciate the value of this paper money. France at first enjoyed a wave of prosperity such as it had not seen for decades. But the inevitable path of many billions of paper secured by three billions of lands is downward.

Lavoisier, though opposed to assignats, was a member of the committee on assignats, lending his technical advice to the hopeless task of preventing and detecting counterfeiting. Once more he was in the laboratory investigating the best types of paper, qualities of ink, making of plates. It was all to little avail. No one could stop the influx of counterfeit paper from abroad. People who had rarely seen money of any kind could not be critical judges of this new paper money.

With the Declaration of Rights finally signed, with the drafting of the new constitution well under way, the first phase of the Revolution was over. France settled down to a semblance of internal peace and good-will.

July 14, 1790 is at hand. All France turns out to celebrate the Feast of the Federation and swear allegiance to the nation. On

the great Champ-de-Mars is gathered most of Paris. Conspicuous as the hero of the day, marshal of the great movement is La Fayette upon his white charger. It is a magnificent pageant which outdoes even the Ancien Régime.

Even to Lavoisier it seemed that the Revolution was over. The goal of constitutional monarchy had been attained. He wrote to Black in 1790: "The plight of public affairs in France for the last year has slowed up the progress of science . . . but we hope that peace and prosperity will follow the troubles which have befallen us and which were inseparable from a great revolution."

To Franklin he wrote as early as February 1790: "We regard the Revolution as finished, irrevocably. There is still a weak royalist party which makes a feeble attempt at strength. The constitutional party, on the other hand, is numerous including among its members the intelligent and enlightened citizenry. The moderates who have kept their heads during the excitement think that circumstances have already carried us too far, that it is a pity to have stirred up the people so, that it is imprudent to place in power those who ought to obey, and that it is to be feared that the new constitution is meeting with opposition from those for whom it is made."

Here Lavoisier again reveals his ideals of government. His democracy was Washington's type, not Jefferson's. He believed in government by the educated intelligent group, not by the people at large. His attitude was typical of the leading liberals of France. The early Revolution was led by the middle class with the aid of liberal aristocrats. But within this great middle class there was still disagreement. Some, like Lavoisier, thought the reforms had gone far enough. Others, especially those of the lower middle class, felt that there was much yet to be done before true democracy could come to France. From this group would come the later leaders of the Revolution, men of high ideals, sincerity and honesty, but also men possessing the crusading spirit of demagogues, the ruthlessness of justice, the thoroughness of finality.

Lavoisier, in 1790, had some suspicion that the future might be troubled, but he had no realization that he was at the moment standing in the calm, low, dead-center of a hurricane, a hurricane which had run but a small part of its destructive course, whose circular blasts would soon return to whirl him with the rest of his kind into the very vortex.

Public Service

THE Revolution was virtually over, or so thought Lavoisier and men of his stamp at the beginning of 1791. But this year would bring profound changes in the feelings of the nation toward its constitutional monarchy. In the fall of 1790 the Assembly had passed the Civil Constitution of the Clergy establishing a new order. Both priest and bishop were to be elected to office, paid by the state and subject only to the constitution. This administrative separation of the French Church from Rome was certain to cause trouble. More than fifty per cent of the clergy refused to take the new oath and were disrobed or became non-juring priests. By the spring of 1791 religious strife was flaring up in the provinces.

Louis, regretting that he had ever signed the Civil Constitution and regretting that he had given even grudging support to the Revolution, began entertaining ideas of fleeing the country—and marching back at the head of a victorious army of noble émigrés. His resolve was deepened when a Paris crowd at Easter time held up the royal carriage to prevent the royal family from attending mass administered by a non-juring priest. Had Mirabeau lived he might have prevented the fiasco of flight; he had power in the Assembly and influence with the king. But dissipation more than hard work brought the great Mirabeau to the end of his career in April 1791.

In June came the abortive attempt of the royal family to flee the country, an attempt dominated by the mistakes and inertia of Louis, an attempt which reached its ignominious climax one hour short of success in the town of Varennes. Back to Paris came the dejected royal family, in its dusty lumbering coach

escorted by an angry multitude, back to the Tuileries and captivity. The king was suspended from office only to be reinstated again when he showed himself penitent. But the flight frightened many of the conservatives into thinking that the Revolution had gone too far. Others, more liberal, like Condorcet, it drove into the arms of republicanism.

A petition to dethrone the king and establish a republic caused a split in the Jacobin Club; the Feuillants, constitutional monarchists, including Sieyès, Lameth, Barnave and others, left the club. But the petition went forward. July 17 was the date set for laying it on the Altar of the Fatherland in the Champ-de-Mars. La Fayette and Bailly determined to stop this demonstration. Out marched the National Guard. A stray shot came close to La Fayette, the guard fired into the crowd. The "massacre" of the Champ-de-Mars was over. It was Bailly who would pay for this—and on the same spot.

Marat, grown vindictive since the days when he was denied admission to the Academy of Science, has begun to denounce all early leaders of the Revolution in his sensation-mongering journal, *Ami du Peuple*. In a pamphlet, he denounces the Academy as a band of charlatans. Monge, Laplace and others do not escape his wrath, but he reserves for Lavoisier the choicest tongue-lashing: "Lavoisier, putative father of all noisy discoveries; he has no ideas of his own so he appropriates those of others; but since he cannot understand them he abandons them again as easily as he adopts them, changing systems as he does his shoes. In a space of six months he has picked up in turn the doctrines of fire, igneous fluid, latent heat. In shorter spaces I have seen him first infatuated with pure phlogiston then ruthlessly denouncing it. Some time ago, following the lead of Cavendish, he discovered the secret of making water from water. Then, imagining that this liquid is composed of pure air and inflammable air, he changed it into combustibles. If you ask me what he has done to warrant such praise my reply is that he has got for himself an income of one hundred thousand livres, has placed Paris in prison with his great wall, has changed the term acid into oxygen, phlogiston into azote,

marine into muriatic, nitrous into nitrite and nitrate. These are his claims to immortality. Proud of his great achievements, he rests on his laurels while his parasitic followers praise him to the skies."

If this is an example of Marat's real understanding of Lavoisier's work in science, it is little wonder that he was never accepted for membership by the Academy. The whole thing is a series of misstatements. But, these were no doubt deliberate; the pamphlet was intended for popular consumption. Taken all in all, Marat's jumbled accusation was in truth high praise of Lavoisier's genius. Marat, capable scientist, in his own estimation, could not even follow Lavoisier's train of thought. This scurrilous attack by Marat needed no answer. Lavoisier gave none. But the attack, nevertheless, had its results in bringing both the Academy and Lavoisier before the public eye in an unfavorable light. The seeds would bear their bitter fruit at a later date.

Not satisfied with attacking Lavoisier's scientific achievements, Marat next turned to his business life. He could find nothing of moral scandal, nothing even of financial scandal except his association with the farm and the building of the wall around Paris. But an attack on the administration of powders would prove popular. Lavoisier had termed Marat a charlatan; well, here was Marat's answer, published in the *Ami du Peuple* on January 27, 1791. "I denounce you Coryphеus of charlatans, Sieur Lavoisier, son of a land-grabber, pupil of the Genevese stockbroker [Necker], *fermier-général,* commissioner of powders, administrator of the Discount Bank, secretary to the king, member of the Academy of Science. Just to think that this contemptible little man who enjoys an income of forty thousand livres has no other claim to fame than that of having put Paris in prison with a wall costing the poor thirty millions, than that of having transported powder from the Arsenal to the Bastille on the night of July twelfth and thirteenth, a devil's intrigue! And now he seeks nothing less than to get himself elected administrator of the Department of Paris. Would to heaven he had been strung up to the nearest

lamppost on August 6th; then the electors of Culture would not need to blush for having elected him."

Marat overlooked a few of Lavoisier's titles in his diatribe. He might have added: secretary of the important national Committee on Agriculture, of the Club of '89, alternate deputy to the States-General, member of the Royal Society of Agriculture, the Royal Society of Medicine, the Helvetic Society of Basle, Royal Society of London, the Harlem Society, the Padua Academy of Science, the Philosophical Society of Philadelphia, and many others of less import.

This attack, recalling as it did the unpleasant powder episodes and appearing in Marat's popular journal where all might read it, hurt Lavoisier's reputation more than a little. If indeed he was attempting to secure election to the office of administrator of the Department of Paris, he was doomed to disappointment. Talleyrand, onetime bishop of Autun, was to hold that important post.

More than one historian has accused Marat of responsibility for the death of Lavoisier. That he was directly responsible is, of course, not true. Marat went to his death under the sharp knife of Charlotte Corday a full year before Lavoisier died. That he would have done all in his power to bring about Lavoisier's death had he lived there can be little question. But even though he has no direct responsibility there is an indirect chain of evidence which leads to his very door. It leads through the person of Antoine Fourcroy, onetime disciple of Lavoisier —and disciple again after the master's death.

Like Marat, Fourcroy was a fluent speaker and writer; like Marat, rebuffs in earlier days had left their mark upon him; like Marat, he became rabid against the leaders of the early Revolution. Though he never reached the prominence of Marat, he nevertheless molded himself on the pattern of Marat, took his cues from this master of rapacity and carried on his work from a post on the important Committee of Public Instruction, and later as an agent of the powerful Committee of Public Safety.

Scarcely had Marat finished his attack when another blow struck Lavoisier. It was the abolition of the *ferme générale.*

At last the cry of ages was being answered; in March 1791, the National Assembly abolished the ancient financial octopus. It was given two years in which to finish up its tangled affairs. Since Lavoisier was not a member of the committee appointed to do this work, his official connection with the organization ceased in 1791. Yet, three years later, he was still a farmer. Once a farmer always a farmer, it seemed!

Loss of income from the farm did not trouble Lavoisier. He was still anxious to serve his country, anxious to employ his financial talents for the benefit of a free nation. He sought appointment on the new tax board but found that his name had been erased from the list of eligibles. He sought appointment as administrator of import taxes in Paris. Again his name was erased. Powerful influences were working against him. Marat?

The transfer of powder to the Bastille, the unfortunate powder episode of August 6, 1789, the incident of the Vincennes fortress supposedly stocked with powder from the Arsenal, all left their trails of suspicion in the minds of the people. The powder commissioners were plotting with the royal forces; they would blow up Paris; they were providing the enemies of France with ammunition. "Down with the powder commission!" screamed pamphleteers. "Hang them!" shouted Jacobins in meeting.

Forced thus to defend themselves against attacks, the commission prepared a pamphlet, largely the work of Lavoisier, setting forth the things it had accomplished. "Public officials," wrote Lavoisier, "entrusted with a national and a difficult service must have the confidence of the people. . . . The more unreserved is their devotion to the nation and the greater their exposure to the dangers inseparable from their work, the more sensitive they are to injustice and to the importance of preventing the swaying of popular opinion. . . ." He then pointed out the savings effected by the commission, the removal of right of search, the higher efficiency of the powder and the reserve stocks accumulated through years of effort. The supposed transfer of powder to the Bastille was, he explained, merely the result of an official order to the commission. In connection with the episode of August 6, he called attention to the fact that

there had been no attempt at secrecy or evasion. All loading had been done in broad daylight. At the end of the report came a personal note describing the qualifications and achievements of the commissioners; it was an attempt to disarm suspicion.

Lavoisier, with his objective method of writing, was, however, no match for the pamphleteers of the day, no match for the fiery Jacobins, his accusers. It was not a part of his nature to become passionate and excited over facts, to conceal truth or to exaggerate falsehood. Instead of waxing eloquent in a glorious cause, he stated merely clear, cold facts which only the intelligent would ever pause to weigh. It is doubtful if his pamphlet had the slightest effect in removing suspicion, if, indeed, it was even read.

In spite of the bitter attacks which had been levelled at him by Marat and others, Lavoisier was still held in high esteem by those qualified to judge true merit. When the National Assembly decreed that a National Treasury should replace the old royal treasury, Lavoisier received appointment to the new treasury commission consisting of six able financiers. He accepted the appointment provided he might serve without pay and retain nominally his place on the powder commission. He wrote to Delessart: "I ask permission to serve in this new position without salary. The income which I enjoy as commissioner of powders, for the very reason that it is modest, is in conformity with my manner of living, my tastes and needs; at a time when many citizens are losing their worldly goods I could not consent to profit by a double salary."

The letter was published in the *Moniteur* for April 7, 1791. It was, obviously, an attempt to disarm the suspicion directed against all wealthy men. True, Lavoisier's tastes and needs aside from the scientific were simple, but he could have lived handsomely without any salary at all. His knowledge of psychology in handling people seemed to be, throughout life, his weakest point. It brought him numerous enemies, few friends.

One wonders, too, just why he clung so tenaciously to his post in the powder commission. He had no need of the salary; the position had placed him in a most suspicious light; his experimental work on powder was done; the institution was

functioning smoothly. Why did he insist on staying on? Perhaps he felt himself indispensable to the work; perhaps he felt that he could prevent greater violence by retaining this key post and holding in check unauthorized distribution of powder to all who demanded. The probable answer is none of these. For fifteen years he had lived at the Arensal. His greatest scientific work was done there. His laboratory there was the finest in France, probably in the world. His apartment was a Mecca for all scientists. To visit Lavoisier at the Arsenal had been the aim of every distinguished foreign scientist and every ambitious young French scientist. The Arsenal was his home, his haven, his life; experimentation in and administration of powders was his hobby, his pleasure, his recreation.

The loss of his post as powder commissioner came soon after his acceptance of the treasury position. A shrewd and sudden move in the Assembly reduced the number of powder commissioners from four to three. Lavoisier, with his new post as commissioner of the treasury was, of course, the one to be dropped. Marat again?

Though Lavoisier objected to this move there was little that he could do about it beyond requesting that he be permitted to retain his apartment in the Arsenal. He wrote to Tarbé, Minister of Public Works, "I shall count on your verbal assurance given in the name of the king that I may exercise my right to a post of Commissioner of Powders as soon as there is a vacancy. I shall likewise count on retaining the lease on my apartment and laboratory which I have furnished and equipped at my own expense."

In March 1791 Lavoisier presented to the Assembly his greatest contribution in the field of economic science, a contribution which entitles him to high rank as an economist. For many years he had been gathering data on the problem of agricultural production in France. His connection with the farm and his own experimental work in agriculture coupled with his exact scientific methods of attack, combined to make him an ideal person to make such a study. With the exception of the works of Voltaire and Du Pont on a similar problem, it was the first work of its kind in France and introduced the exact scien-

tific method into the study of economics. Both Voltaire and Du Pont had estimated the produce of the nation at close to one hundred fifty livres per head. Lavoisier's work placed it close to one hundred livres per head. The publication was unique and exact in its method. Each type of produce had its own chapter, its own accounting in terms of seed, labor charges, food, taxes, rents. There were graphs and tables giving population by age, sex, profession, evaluation of wheat, oats, barley, meat and wine. It was, in fact, a stupendous piece of work. How Lavoisier with the press of his many duties was able to accomplish it is still a mystery. Unfinished though it was, it showed clearly the error of the National Assembly in its assumption that it could raise a produce tax of two hundred forty million on a taxable wealth of one billion two hundred million. In apologizing for the incompleteness of his work Lavoisier said, "I have taken up this work twenty times and though I realized its importance and wished to publish the results for the benefit of the tax commission I have been continuously deterred by the press of other work and have been unable to finish it." In recommending the printing of this contribution by the National Assembly, Roederer said, "M. Lavoisier has made exact calculations of details of great interest. If the Assembly prints it, it will be a boon to all agriculturalists and all citizens." The pamphlet was duly printed.

Another position of honor, trust and much labor fell to Lavoisier in 1791 upon the death of Tillet, long-time treasurer of the Academy of Science. Tillet's long illness and the uncertainty of securing financial assistance from the Assembly had placed the financial affairs of the Academy in a precarious and tangled state. To Lavoisier fell the task of unravelling the snarls and begging support from the Assembly. With tireless energy he attacked these problems, continuing the battle for financial support, carrying from his own pocket many a penniless academician till the Assembly grudgingly voted funds, fighting against the powerful influences at work to demolish the ancient institution, and at the last virtually carrying the Academy on his own tiring shoulders.

As early as 1790, the Academy had undertaken, at the instigation of Talleyrand, the task of establishing for the entire nation a uniform system of weights and measures to replace the chaotic varieties of systems in vogue. Failing in its efforts to secure the cooperation of the Royal Society of London in developing an international system, the Academy went ahead with the project alone. It is, indeed, unfortunate for the entire world that there was this lack of cooperation. It is claimed that the Royal Society never received a communication requesting cooperation.

Little recognized as it is, one of the greatest contributions of the French Revolution to Europe and to science throughout the entire world was the metric system of mensuration, established on the basis of careful scientific work, built up of convenient decimal units in multiples of ten and used today universally by scientists in their work.

Directing this work for the Academy was a committee consisting of Borda, Lagrange, Laplace, Monge and Condorcet. To a sub-committee consisting of Lavoisier and Haüy fell the task of determining the exact density of distilled water. This would serve as the unit basis of weight in the new system. In 1791, Lavoisier was appointed secretary-treasurer of the commission in addition to his other duties. When Monge withdrew from the commission in 1792 to become Minister of Marine, Lavoisier took his place.

The history of this important commission so intimately associated with the last days of the Academy, is, in fact, the history of the Academy itself in its death struggle. Through all of these trying times, Lavoisier struggled to keep this work moving as he struggled to save the Academy.

By October 1791 the National Assembly had put the finishing touches on the constitution. The king had taken his oath of loyalty—with mental reservations. France started on her brief experiment in constitutional monarchy with the election of the new Legislative Assembly, representative of the great middle class of propertyholders. To the moderates it seemed that the Revolution was over. But, was it?

The rest of royal Europe looked with suspicion at this experiment in government. The rulers of Prussia and Austria had already issued the famous Declaration of Pillnitz, declaring that the reestablishment of order and absolute monarchy in France was the concern of all the rulers of Europe.

Even England, which at first looked with favor on the liberalization of France, now joined in the condemnation. But there were a few who still cheered. In the front rank of these, as might be anticipated, was Joseph Priestley. He came closer to hanging from a lamppost in '91 than Lavoisier had in '89, and all because he cheered the French Revolution. The French Revolution drove Joseph Priestley from England!

July 14, 1791 was the date set in Birmingham for celebrating the anniversary of the fall of the Bastille. There was to be a banquet, attended largely by Dissenters, at the Royal Hotel. Outside the hotel were royalist mutterings, threatenings. "Down with the Dissenters! They are leading England to revolution! A plot of revolt is afoot!" A few paid agitators can accomplish wonders. "For Church and king!" rings the cry. Rocks crash the hotel windows. The banqueters flee for their lives. "Where is Priestley?" shout the royalists, "We will hang the dirty heretic!" But Priestley is not to be found. Forewarned of the trouble, he is hiding. To the meeting house of the Dissenters, rolls the mob. With smoke from the glowing embers behind them, they are off again to Priestley's home at Showell Green. Again, no Priestley—but his home and laboratory are hostages. Up they go in smoke. Priestley a half-mile away can see the smoke; he is hurried off with his family for safe keeping to Dudley. For four days the mob threatens all of Birmingham, seeking their prey, the philosophers. Terrified citizens scrawl, "No philosophers here!" on the window panes.

Sorrowfully, but not bitterly, Priestley made his way to London to wait till the storm had passed. Poor, rebellious Priestley, he was never to return to his beloved Birmingham again. On July 22 he wrote his friend, Captain Kierr, chairman of the fatal banquet: "When it will be proper for me to come to you I cannot tell. I fear not before the next Lunar Society. Whether I shall ever have it in my power to collect

another apparatus for experiments is quite uncertain, as indeed is, in a great measure, my settling again in Birmingham though there is no place that I should prefer to it."

From Priestley's many kind friends and sympathizers everywhere poured in letters of condolence, offers of assistance, equipment, home, position. Charles Fox took an active interest in Priestley's claim against the city of Birmingham, a claim that finally netted Priestley £2,502 for a loss estimated at £4,500.

From France, too, came offers of a home, a laboratory, equipment, honors. Through its secretary, Condorcet, the Academy sent condolence to its distinguished foreign member and placed its resources at his disposal.

There exists the rough draft of a letter with corrections and additions written by the hand of Lavoisier and the whole letter probably dictated by Lavoisier, a letter to be sent to Priestley from his fellow chemists in Paris. Though there is no record that Priestley ever received the letter or acknowledged it, its very existence and the friendliness of its tone shows that Lavoisier could be magnanimous toward his English contemporary. It reads in part: "The Chemists of Paris to Dr. Priestley, Greetings.

"At the news of the misfortunes which have befallen you and your escape from their consequences, workers in chemistry, medicine, and pharmacy unite here to express their regards to you. . . .

"You, sir, have opened up new paths in science; you have honored the century and the country which gave you birth; you have been sensible, virtuous and honorable; you needed only persecution to bring you greater fame. . . .

"As a citizen you belong to England, she must make due amends for your losses; but as a scholar you belong to those who know how to appreciate you and it is to the undersigned that you must turn for assistance in restoring the equipment which you employed so usefully in instructing us. . . . What more important service both to us and to science could we render than to place in your hands [these] instruments? . . ."

Priestley's letter to Sir Joseph Banks, president of the Royal Society, is pathetically touching.

"Having lost my whole stock of substances, ores, minerals, earths, etc., for the purpose of experiments and wishing to replace them as expeditiously as possible, I shall be obliged to you if you will mention my situation to any of your friends whose laboratories are furnished and who may have anything to spare to set up a broken philosopher. . . . "

Though Priestley found numerous friends in his days of trouble, he still had plenty of enemies. Attempts to establish a laboratory at Hackney met with renewed threats of violence. Churchmen shunned him, royalists abhorred him. No less a person than King George wrote of him, "I cannot but feel pleased that Priestley is the sufferer for the doctrines he and his party have instilled, yet, I cannot approve of their having employed such atrocious means of showing their contempt." To Priestley it was a different matter. He wrote, "The spirit of bigotry nearly bordering on that of persecution being encouraged by the Court is greatly increased in this country which makes it, tho' not absolutely unsafe, yet unpleasant to live in."

Even the Royal Society, composed of supposedly objective scientists, could not divorce science from emotion. Churchmen and King's men as they largely were, they turned a cold shoulder on their famous member from Birmingham. Priestley wrote in 1793, "As for the Royal Society, I see myself regarded in so unfavorable a light by the most considerable members of it that I never go near them."

Sadly, Priestley prepared to leave his native land where he was no longer welcome. Renouncing his fellowship in the Royal Society, he set sail on April 8, 1794, for far-off America. "I cannot," he wrote, "refrain from repeating again, that I leave my native country with real regret, never expecting to find anywhere else society so suited to my disposition and habits, such friends as I have here (whose attachment has been more than a balance to all the abuse I have met with from others). . . . I can, however, truly say that I leave without any resentment or ill-will. On the contrary, I sincerely wish my countrymen all happiness; and when the time for reflection

shall come, they will, I am confident, do me justice . . .; and perhaps I may, notwithstanding my removal for the present, find a grave (as I believe is naturally the wish of every man) in the land that gave me birth."

England has had plenty of time for reflection and she has forgiven her rebellious son in full. His memory is her pride, her joy, her glory in science. She looks just a little shamefacedly toward a graveyard in the town of Northumberland, Pennsylvania, where the remains of Joseph Priestley still lie. Priestley's wish was not fulfilled. America could not give up her little share to greatness from association with the stuttering "heretic." She has made his grave a shrine, his home a monument to the chemistry of a new world. At this shrine American chemists worship the memory of an Englishman, for Priestley never became an American citizen.

In Northumberland, he found a sort of peace; he found time to pursue the labors of science, to discover the composition of the gas, carbon monoxide, the gas which he had so badly confused with hydrogen at an earlier date. This was his one scientific contribution of any importance in America. One close link to the past he retained: it was phlogiston. He continued to gather evidence supporting this theory. In 1795 he wrote, "I am now in a course of experiments by which I think I shall prove pretty decisively that what I have called the phlogistication of air is really so and not the mere absorption of the pure part of it as the French chymists suppose." In 1803 just a few months before his death he wrote his last scientific paper, *The Doctrine of Phlogiston Established and that of the Composition of Water Refuted!* It was good that he could not live to see how this last defense was accepted by the world of science. Phlogiston had been already dead for a decade—a dozen Priestleys could not disinter it now.

What did Priestley think at the last of Lavoisier? Unfortunately, we do not know. Priestley never spoke or wrote about him. His true feelings were his own. We know only that he was never swayed far by jealousy, forgave his persecutors, held no ill-will toward men. Assuredly he held none toward the man who had taken his great discovery to mold a new chemistry

around it. Nevertheless, he probably regarded Lavoisier as a royalist, who profited much from the Ancien Régime.

As a moderate, Lavoisier watched, with growing concern, the development of bitter party strife and the increasing danger of war following the gathering of the new Legislative Assembly in October 1791. The Assembly soon found itself split into three parts. High upon the left sat the more radical group known as the Girondists. On the right sat the Feuillants, the only real friends of the constitution. In the center sat the great majority of the deputies, the plainsmen, who had given allegiance to neither the right nor the left. With Brissot, Vergniaud and others for their leaders, and with Condorcet as their first god, the closely-knit minority of the left was soon leading the plainsmen by the nose.

First, the Assembly passed edicts against the troublesome émigrés and the non-juring priests. These were promptly vetoed by the king who thus paved the way for the fall of the monarchy. Then, attention was turned toward war. True, there was little reason for war, but the left saw in it a possibility of overthrowing the monarchy, and the right, a possibility of reestablishing the lost authority of the king. The king and queen, conniving with the émigrés and the enemies of France, saw in it release from their bondage.

In March 1792, Louis, thinking perhaps to attach the stigma of a military defeat to his enemies, replaced his loyal Feuillant advisers with a Girondist ministry. In it were Roland, the elderly unassuming husband of ambitious Madame Roland, Clavière, a Swiss authority on finance, and Dumouriez, an adventurer, soldier and politician. War was declared on Austria April 20. France would see final peace again only with the battle of Waterloo, twenty years later. Prussia soon joined Austria. Had these two countries not been busy, with Russia, partitioning Poland, France would have fallen easy prey to the armies of Francis II and Frederick Wilhelm. As it was, the French army in Belgium broke at the first sight of the enemy.

This cowardice must be a result of the machinations of the enemies of Revolution, the king among them, reasoned the

Girondists. In retaliation the Assembly was persuaded to pass three edicts: one, again attacking the non-juring priests, and thus striking the king in his softest spot, one disbanding the king's constitutional guard, and one creating an armed camp of "federates," composed of loyal Jacobins around Paris. Perversely, the king signed the edict abolishing his own guard and held up the others. On June 10, Roland read the king a lecture, written by Madame Roland, insisting that all the decrees be signed and adding significantly that further delay would place his majesty under suspicion of being an "accomplice of the conspirators." Louis said nothing, put the impertinent letter in his pocket and two days later peremptorily dismissed Roland and Clavière, then vetoed the two decrees. Three days later Dumouriez was also out of office.

Lavoisier, a member of the former Club of '89 and a believer in constitutional monarchy, was at heart a Feuillant. As such, he was called to a number of public posts. In January 1792, he was appointed a member of the advisory board of the Bureau of Arts and Crafts. This unusual institution was created for the purpose of advising the government concerning useful inventions. With Lavoisier on the board sat Cousin, Hallé, Borda, Laplace, Lagrange, Trouville and Coulomb. It was truly a board of eminent scientists. In 1793, Lavoisier became its president.

Strangely enough, his chief contribution to the work of the board was not in the field of science but in the field of education. Such was the versatility of the man that he could turn from problems of science to those of economics, to those of finance, to those of charity, to those of education—rendering most important contributions in each field. Each he handled in his objective scientific manner giving careful consideration to details, making provision for all difficulties, and bringing all angles of the problem into view.

He was no stranger to problems of education, for he had established at his own expense a primary school near his estate of Fréchines. Talleyrand evidently regarded Lavoisier as something of an authority in this field for he wrote, "I have the honor of sending to M. Lavoisier a copy of my report on public in-

struction. . . . I am in the process of correcting errors and would like to have the advice of men who enlighten and fix public opinion. Would M. Lavoisier have the kindness to criticize the mistakes strictly and frankly."

Lavoisier's proposed system of education, though it did not differ greatly in principle from that proposed by Condorcet, nevertheless did contain a number of novel and advanced ideas, ideas which even today have not been fully realized in democratic education. He believed in free education for all children. "It is," he wrote, "a duty which society owes to all children." For small children he advocated the use of pictures in teaching language. "May the written language, if possible, be the language of pictures so that the idea may never be separated from the word." The close association of ideas and names is directly traceable to his thoughts on chemical nomenclature. His most novel suggestion was the establishment of vocational schools in the upper levels. "There exists," he wrote, "no example of this because there has been no nation which was concerned with the interests of its industrial classes. . . . We must not encourage exclusively certain parts of education and ignore others. The arts, the sciences, and literature are bound together with invisible ties which cannot be broken with impunity."

Lavoisier would never live to see his plan of education put into operation. But strangely enough, many of his ideas would appear in the system established by Napoleon's director of public instruction, Antoine Fourcroy! What a strange fate which left to Fourcroy the legacy of carrying out his master's ideals in both science and education!

In the treasury, too, Lavoisier went to work with his usual energy. "He established such an exact system of accounting that one knew the condition of the treasury day by day." In November he appeared before the newly organized Legislative Assembly to explain his accounting system. In January 1792, he issued a pamphlet on the state of the nation's finances. "In a time," he wrote, "when all things good and bad alike are exaggerated . . . it is advisable to discuss the finances of the nation dispassionately and with rigorous arithmetic." He then went on to show in careful, exact figures the financial state of

the nation and to provide data for the determination of the annual budget. The pamphlet, however, did not appear over Lavoisier's signature. It went unsigned. The name of Lavoisier was not one to conjure with at the moment.

But, the work in the treasury department was discouraging. Tax receipts were small; expenses, high; war, imminent. To Nompère, Minister of Interior and cousin by marriage, Lavoisier wrote, "What you have feared in the return of taxes is only too well realized; payments to the treasury on land and personal taxes are extremely small, on the other hand, we may be dragged into war by the too precipitate action of the Assembly even though no one desires such a thing. What is happening to us is what happens in all popular governments: moderation is not the rule though a constitution philosophically sound should bring calmness."

In February, Lavoisier tendered his resignation as commissioner of the treasury. He was no longer seeking the light of public office; he was no longer the ardent reformer of a few years back. He was weary; the Revolution had passed him by as it had other men of his caliber. He longed for the quiet of his laboratory, for the peace which science could bring to him.

His service to the treasury was recognized at least by his colleagues: "It is difficult," they wrote, "to express our regret at the loss of our colleague. The administration could not be deprived of a better man, a man of more tireless activity, of higher ideals."

Perhaps Lavoisier resigned from the treasury in order to regain his lost position as Commissioner of Powders. There was a vacancy in the commission; Clouet, a real victim of Bastille Day when he was mistaken for De Launey, had finally died. Lavoisier exercised his right to this vacancy and was appointed. But things were sadly changed in this new year. Appointees of the king were far from popular; they were, in fact, suspects. The Powder Commission could not withstand the public onslaught much longer; like other legacies from the Ancien Régime it was doomed.

Seeing with acute vision what was soon to happen, or being, perhaps, forewarned, Lavoisier resigned once more, this time

from the Powder Commission. Even now, however, he was not willing to sever all relationship with this work which had meant so much to him, and with the home which had been his for so many glorious years. He wrote to Clavière, Minister of Finance, "The State will have four directors instead of three. I shall relinquish my duties and title to serve my country as a free independent man asking nothing from authority."

But even free service was to be denied him; he soon realized the necessity of divorcing himself not only from the Commission but from the Arsenal as well. Purchasing a house on the Boulevard de la Madeleine, he removed his elaborate equipment and furnishings from his home of many years to start anew once more. He was none too soon and perhaps had an inkling as to what was to happen. Three days later agents of the commune entered the Arsenal, arrested the commissioners and placed all papers under seal. Old Faucheux, Lavoisier's colleague of fifteen years, committed suicide. It was the end of the old Powder Commission; the Assembly decreed that none of the former members was eligible for appointment to the new.

Lavoisier was now a free man, free to devote his time to science, the Academy and the Bureau of Arts and Crafts. Surely these were safe pursuits even in time of revolution. But once more he received a call to public life, a call of desperation from his king. Would he accept?

The king was tired of having enemies as ministers. When he dismissed the Girondist ministers he sought men who might be his friends; he even turned to La Fayette, unpopular as the general was with the queen, for advice. It was in this new Feuillant ministry that Louis invited Lavoisier to accept the finance post formerly held by Clavière. It is also likely that Du Pont and Malesherbes, both advisers of the court, urged this appointment on Louis.

Lavoisier's inclusion in this proposed cabinet gives us again an idea of his political philosophy. He was a moderate, a constitutional monarchist, and he remained one till death. It speaks well for La Fayette that he should recommend Lavoisier. He was choosing a man well fitted by experience and training

to fill this all-important post. He was choosing a man, however, whose detached character was ill equipped to cope with rising political demagogues. Lavoisier was not a politician and he knew it. He knew the difficulties and the dangers he would face in this office if he remained true to his belief in constitutional monarchy.

His reply to this offer is also revealing both of his principles and the condition of the times. He did not hesitate to refuse the offer, nor did he hesitate to give his reasons. His praise of his king may sound shallow; it was probably sincere. As yet, a great majority of Frenchmen still believed in their monarch.

"Sire—It is neither through weak fear, far removed from my nature, nor through indifference concerning public welfare, nor a feeling of incapacity that I am constrained to refuse the mark of confidence with which your Majesty honors me by offering me the ministry of Public Revenues. Witness, as I was, of your patriotic sentiments while I served as commissioner of the National Treasury, of your solicitude for the happiness of your people, of your inflexible severity of principle, of your invariable integrity, I feel more strongly than I can express what I am losing in renouncing this opportunity to become the mouthpiece of your sentiments in behalf of the nation.

"But, Sire, it is the duty of an honorable man and citizen not to accept an important place unless he has hopes of fulfilling such obligations to their fullest. I am neither Jacobin nor Feuillant; I belong to no society or club. Accustomed to weighing things by conscience and reason, I could never consent to alienate my opinions. I have sworn allegiance to the constitution which you have accepted, to the powers constituted by the people, to you, Sire, the constitutional monarch of France, to you whose misfortunes and virtues are little understood.

"Convinced as I am that the legislative body has gone beyond the limits of the constitution what could a constitutionalist minister do? Incapable of conciliating his conscience and principles, he would seek in vain the authority of law to which all Frenchmen are bound by solemn oath. If he advised the resistance to which your Majesty is constitutionally entitled,

it would be represented as a crime; he would perish a victim of his duty and the very inflexibility of his character would become a source of new misfortunes.

"Sire, permit me to consecrate my work to the service of the state in less elevated positions where I can, perhaps, render greater and probably more durable service. Devoted to public education I will work to enlighten the nation. Soldier and citizen, I will carry arms in defense of the fatherland, of law, of the constitutional representative of the nation.

"I am, with deep respect for your Majesty, your very humble and obedient servant."

Lavoisier's wisdom in declining a post in this short-lived ministry was soon evidenced. Vengeance for the fall of their ministry was not to be denied the Girondists. Events followed one another in confused precipitate order.

On June 20, Santerre's organized mobs invaded the Tuileries, forcing the king to don the red cap of the Jacobins, the queen to humiliate herself to the insults of fishwomen and drunken harlots. La Fayette, now a general at the front, hastened to Paris, denounced the Jacobins and laid plans to remove the royal family to the protection of his troops. But, the court would have none of him.

By the 10th of July, the La Fayette ministry, helpless and hopeless, had deserted; once more the Girondists were in power. On the 14th, anniversary of the fall of the Bastille, no one cheered the royal family when it appeared at the Champ-de-Mars for the celebration. On the hot dusty roads from Marseilles, the "Men of Marseilles," patriotic Federates, were moving toward Paris dragging their cannon behind them, swinging to their new marching song, "The Marseillaise."

The fatherland was in danger, declared Hérault. The Austrians were fighting their way toward Paris. Patriotic fervor rose to the crisis. "Treason at the Tuileries," came the cry. Brunswick's Manifesto threatening the armed might of Europe against France if a finger were laid on the royal family merely increased the tumult against the king. The end of monarchy

was at hand. The "Men of Marseilles" augmented by many more Federates were ready to march on the Tuileries. It was the eve of August 10.

The king makes a woeful figure as he attempts to review his guards; only the Swiss stand at attention. Most of the moderate deputies have deserted the Assembly. All Paris is demanding that the king be deposed, still the Assembly has not acted. In the early dawn of August 10, Federates and National Guards converge on the Tuileries. A few of the faithful, Malesherbes and Du Pont among them, draw swords to defend their monarch to the death. But the monarch has no stomach for a standing fight. The whole royal family is hustled off to the questionable protection of the Assembly, leaving the Swiss guards to die defending an empty palace.

In the Assembly, Louis listens attentively while Vergniaud moves that the king be deposed. There is no question of the outcome; the vote is unanimous. France no longer has a king; she has Louis Capet, an embarrassing hostage to a republican state.

While the Tuileries was being attacked, Lavoisier, a member of the National Guard, was on guard duty at the Arsenal. He had given up his public posts; the Academy was in vacation; it was time to go to Fréchines once more to enjoy, for the last time, the peace of the country home. Paris, even now, was becoming a dangerous place for constitutional monarchists. When the Lavoisiers returned, it would be to a different Paris, a Paris in a state of nerves over the approaching enemy, over the king's recently discovered treasonable correspondence with that enemy, a Paris in which the Legislative Assembly had lost its power to the provisional governmental committee headed by Danton. There was religious revolt in the Vendée district. There was rumor that the prisons, filled with aristocrats and non-juring priests, might pour forth their multitudes to massacre good patriots. The Paris communes took matters into their own hands; the prisoners were massacred instead. Thus passed the September Massacres. The National Convention, representing the newly born French Republic was already in

session. Condorcet was there framing a new constitution, this time, for a republic. It was to be, not for the rich, not for the well-to-do but "for all men."

Could Lavoisier have foreseen what lay ahead he might better have remained at Fréchines.

Death of the Academy

ANTOINE FOURCROY resumed his seat in the Academy hall; it was the meeting of April 25, 1792. His blow was struck. A silent hall greeted this demand of patriot Fourcroy that the Academy purge itself of "certain members tainted by royalism," of "certain members guilty of incivism." The Academy of Medicine, pointed out Fourcroy with sharp insistence, had already made such a purge. The Academy of Science must prove its loyalty by a similar move. If Fourcroy was a second-rate scientist he intended to become a first-rate patriot. As first proof of patriotism, he chose to attack the Academy, his Academy, Lavoisier's Academy.

By what right did Fourcroy make such a demand? Who in the Academy was disloyal to the nation? Had not many of the ardent leaders of reform come from the Academy itself? What about Bailly, Condorcet, Monge, Rochefoucauld, Hassenfratz, Lavoisier and many more like them? What about Malesherbes, Turgot, Quesnay, D'Alembert? Were they not among the earliest reformers in France? Yes, men of the Academy had been leaders of reform but not the kind of reform that patriots of the Fourcroy type demanded. The pendulum of revolution had long since passed them in its swing.

The Academy was not a political body but a scientific institution devoted to the cause of pure science and to improving the welfare of the nation. It exercised no control over the political opinions of its members. Nevertheless, it was a child of the Ancien Régime; that was enough to condemn it. Liberal as it had seemed a few years back, it was now, through the rapid

march of events, conservative. It was a privileged body standing in the way of individual freedom.

What could be the answer to Fourcroy's patriotic demand? To acquiesce in the purge would be to plunge the Academy into a maelstrom of bitter acrimony. To deny, would be equally disastrous, it would invite the closing of its doors. No doubt Fourcroy enjoyed the dilemma in which his fellow members found themselves.

It was Cousin who found the way out of the difficulty. Send the list of members to the minister; let him strike off the names of those guilty under Fourcroy's charge. Fourcroy was checkmated in his attempt to turn the Academy against itself. He would not forget this check. He would return to the attack later when times and his powerful position favored him better; he would return driven by a patriotic urge which could not, would not, be stopped.

When Lavoisier returned from his last trip to Fréchines in October 1792, he plunged once more into the work of the Academy. He must remind Roland, again minister, of his promise of a room in the Louvre for a chemical testing laboratory; he must remind academician Minister Monge of sums due to finance the printing of *Connaissance des Temps*.

Then, too, a little judicious flattery in the right place might not hurt the Academy. He wrote to Monge, "The Academy is happy to have as interpreter to the National Convention a scientist and an Academician." Monge, now a patriot, remained cool to the praise.

Nor had Lavoisier forgotten his old friends in their hours of need. The fall of the monarchy had ended Du Pont's distinguished public career. Without funds, without prospects in public service, Du Pont decided to try the publishing business. All of literate France was reading—reading books, pamphlets, newspapers, anything. Presses were working day and night to supply the demand. Where should he turn for financial aid but to his good friends M. and Mme. Lavoisier? From them he borrowed 710,000 livres to start the business. The loan was secured by a mortgage on Du Pont's country home, Bois-des-Fossés, at Chevannes in the district of Nemours. It was to be repaid in

twelve years and carried an interest rate of 4 per cent. "The printing house I have started," wrote Du Pont to Mme. Dalmas, "and which is very large, is founded entirely on credit and on the kindness of some capitalists who have advanced the money."

Not only did Lavoisier establish his friend in business but he saw to it that this firm did his own printing as well as much of that of the Academy. In 1793, Pierre du Pont found it expedient to leave Paris; he was a marked man. From his country home he directed much of the work of the firm, leaving the active supervision of it to his son, E. I. du Pont, who had left the employ of the Powder Commission when Lavoisier went to the Treasury. Letters between father and son give us a picture of the amount of work Lavoisier was turning over to his old friend and his young protégé. "More business," wrote P. S. du Pont to his son on March 8, 1793, "M. Lavoisier two, the Academy three, the Republic two, odd jobs one."

It is evident that Lavoisier could not divert all of the printing of the Bureau of Arts and Crafts to his friend, as the following despairing letter written by Du Pont a few days later indicates: "I would not have believed that M. de Borda, of whom I am very fond, would have gone to Didot and have made arrangements with him unless I had refused. Oh! my friends, there are no friends left." Again in April, after Lavoisier had started his project of gathering together and printing in eight volumes his complete works in science (a project which was cut short by his death) he wrote: "M. Lavoisier tells me, my dear child, that besides the *Académie* and the *Connaissance des Temps* you must print five volumes of his works between now and October. . . . It is not the printing that troubles me, nothing could be easier, but the composition and above all the corrections. The edition must be as beautiful as is possible and above all correct. If I were in Paris, I would work at it day and night and would not allow a final printing until I had corrected not only the third proofs but the fourth and if necessary the fifth." Again, "I have promised Lavoisier that his printing shall be beautiful, rapid and correct." In May, young Du Pont is hard at work on this project. He writes to his loyal wife who is caring for her father-in-law at Bois-des-

Fossés, "I shall be very busy here for some days getting M. Lavoisier's work well started." In July came the contract to the firm of Du Pont for the printing of volumes of the Academy for the years 1790, 1791 and 1792.

Lavoisier and the elder Du Pont corresponded regularly every week through all of these troubled days till prison bars put an end to it. In June, the elder Du Pont requests his son to "See M. and Mme. Lavoisier. Ask them if they did not receive one of my letters. They know how punctual I am. . . . Ask them too, whether they wrote me on the two Thursdays—the 23rd and the 30th." Not only was mail service irregular in these days but in addition, many letters were opened by the censors. Soon, Du Pont was no longer mentioning Lavoisier by name. He became M. Lav, M. Lavo, and finally, "our friend the scientist." Meddlesome eyes were looking for victims for the guillotine. The elder Du Pont, early trained in medicine, became "the Doctor" in this interesting correspondence which traces in a unique manner the last days of Lavoisier.

So strong was feeling against all academies becoming in the Committee of Public Instruction and in the Convention, in the fall of 1792, that the academicians decided to use all means in their power to combat the rising tide of disfavor. All draperies and tapestries were removed from the quarters as unbecoming to a republican institution. A previous relic, a mammoth nugget of gold, bequeathed to the Academy, was turned over to the National Treasury for what it would bring. On Sunday, November 25, the Academy went in a body before the National Convention to present its important unfinished memoir on the work of the commission on weights and measures. Borda read the report. There were, perhaps, sneers from the Mountain, the silence of contempt from the Jacobin section as these scientists, relics of the old régime, appeared in their pitiful attempt to stem the tide rising against them. In the main, however, the report was well received. Grégoire, president for the day, was a firm friend of the Academy. His response was courteous and honest. "The National Convention," he said, "rejoices in the success of your important work. Long have philosophers attempted to remove the difficulties encountered in systems of

measurement. Through you the universe will owe a debt of gratitude to France. . . . Yours is the glory of discovering for the world that stable unity befitting truth which will link nations together in one of the most valuable conquests of equality. The National Convention accepts your report and welcomes you to its meeting." The Academy was still the scientific center of France.

The philosophers left, satisfied that they had made a favorable impression. But, had they? Three days later came the answer. By a decree of the Convention, the Academy was forbidden to nominate men to vacant places, forbidden to fill its ranks. Thus, it was faced with eventual death when the last member died. But death would come far sooner than that. A mere shadow of its former glorious self, the Academy continued to meet. Minutes were brief; even the names of members present were not recorded. The Academy had enemies within its own hall, enemies who were only waiting for the first suspicious step to turn state's evidence. D'Arcet was director but found scant time to devote to affairs of the Academy. Only Lavoisier remained as an active officer of the dying Academy. He might well have withdrawn from the unequal battle as so many of his colleagues had already done, but he could not bear to see this center of science, which had long been a glory to the nation, destroyed in so heartless a manner. He could not see aged colleagues left penniless without fighting their cause to the end, without lending them money from his own pocket. At his death, he had 20,000 livres outstanding in personal loans. He could not see the important project on weights and measures stopped in its prime and short of success.

It was during these troubled days that Lavoisier received a fine token of the esteem in which the world of science held him. The Royal Society of London awarded to him the Copley Medal, highest award it had to offer. His new system of chemistry had captured England in spite of Priestley and Cavendish. An award which would have delighted Lavoisier a few years before now was an actual embarrassment; it came from a foreign nation, from England, an enemy of France. In times of

international crisis, science becomes ardently national. There were no columns in the Paris papers describing this honor to the leading French scientist of his day. The less publicity, the safer it was for the recipient of this honor.

What paper could bother to print such minor news? Who would listen to the unimportant affairs of an Academy when France was bringing before the bar of the Convention her one-time king, now simple Citizen Louis Capet? Louis Capet, once absolute monarch of all France, once the man whose very word imprisoned men, pardoned men, killed men, sent the nation to war, depleted her treasuries; this virtuous glutton was standing now before his judges a simple being, pathetic, placid, but manly enough at last to command respect even from the hooting galleries. He was guilty of treason, there was no doubt of that. But, should he be executed or merely imprisoned? Old Malesherbes, he who was "twice called to the councils of his master," was there again and for the last time, counsel for the defense. He was digging his own grave, pleading a cause already lost to ears that would not listen.

The Jacobins, now swung to the far left, demand the death penalty. Girondists, relegated to the right, waver but follow their brethren of the Mountain and thereby sign their own death warrants. Even the remnants of nobility vote for death—as the last drastic means of securing armed intervention in the affairs of France. The Duc d' Orléans votes his cousin's death—and will soon follow him. A few call for mercy; Thomas Paine refuses to vote for death even though he leads defiance to kings and priests. Sieyès leads the plainsmen in voting death. "Death to the tyrant," is the final verdict. Malesherbes makes one last reasonable plea, for delay, for appeal to the people. It is useless; Louis Capet will die within twenty-four hours.

The January day is cold. Sleet has covered the ground and made the platform of the new guillotine slippery. Neverthless, every available spot along the two miles from Temple to Tuileries is filled with seething humanity to witness the spectacle. Louis Capet rides slowly, too slowly, in the carriage of minister Clavière—the day of the tumbril has not yet arrived. The square is reached finally; Louis glances with interest at

this unique instrument of execution suggested by the humane Doctor Guillotin. He is divested of coat and cravat; his hair in back is cut short so that the knife will find quick and easy passage through the flesh. Louis objects to but one thing: he does not want his hands bound behind him but he submits even to this indignity with final placidity.

There is a brief moment of silence in which Louis utters his last words, "I die innocent of the crimes laid to my charge. I forgive all who are the cause of my misfortunes. I trust that my blood may assure the happiness of France." Manly words from one who was forced to learn manliness through revolution. The drums take up their rolling dirge. Sanson's hand moves; the knife falls; the drummers rise to a final staccato. In a basket lies the dripping head of Louis Capet.

Torn bits of coat, bits of hair—these are glorious souvenirs seized by the excited mob. Most fortunate are those near enough to dip their souvenirs, their handkerchiefs, pikes, spears, or even bits of paper in the blood of Louis Capet. *Sansculottes* make merry in the streets.

Things seemed to be going well for republican France. The battle of Valmy had temporarily ended the invasion by Austria and Prussia. But the death of Louis changed the picture. All the powers of Europe joined in the coalition against France. Revolt flared up anew in the Vendée and elsewhere. There were bread riots in Paris. A great struggle for power arose between the Jacobins, championing the democratic masses, and the Girondists, representing the upper bourgeoisie.

Through these restless months of early 1793 there was no relaxation for Lavoisier. He was studying the density of water with Haüy, comparing the expansion of copper and platinum with Borda in order to prepare the standard unit of length, the meter. He was securing funds for the publication of Vicq d'Azir's treatise on anatomy, for Jauraret's astronomical tables, for Berthollet's work in applied chemistry, for the work of Sage, bitterest opponent in France of Lavoisier's theory. Even Fourcroy got funds from the Academy for experimental work.

Fourcroy, shaking one fist at the Academy, was opening the other to accept its funds.

In vain did Lavoisier appeal to members of the Convention for funds to carry on these projects and many more. He wrote to Arbogast, scientist, deputy, and member of the important Committee of Public Instruction: "Foreign powers will profit by the transfer of the arts and sciences to their soil. But French scientists still reject indignantly all offers made to them." No answer was vouchsafed. He wrote to De Morveau, also a member of this important Committee, he who had once collaborated in the new chemistry, he who had once praised Lavoisier's genius. De Morveau was now as silent as a tomb. Fourcroy, too, was a member of this Committee. Why did not Lavoisier appeal to his former pupil and colleague? The answer is all too obvious; he knew full well what the result would be. Fourcroy had at least shown his hand; the others were silent. He wrote to Garat, minister of the Interior, to the directors of the district of Paris, to the commissioners of the Treasury in a desperate effort to obtain funds long overdue. All was useless. There were no funds for the Academy. Monge, Hassenfratz, De Morveau and Fourcroy were riding the Revolution; when the time came they would remember the Academy in their own way.

Why does Pierre du Pont write to his son on March 17, 1793, "I have advised Lavoisier to go to Fréchines and offered him your services and those of Faure to see to his affairs during his absence. Do not speak of it unless he does"? Did personal danger threaten the scientist at the moment? Perhaps he was unable to get his *Carte de Civisme,* that passport required to be carried by every good patriotic citizen. Perhaps his activity, in behalf of the Academy, had become acutely objectionable to certain deputies. In any event, he did not follow the advice of his good friend. He remained at his thankless post.

It was the black of night before a false dawn. Help for the Academy came from a most unexpected quarter. It came in the form of a gallant, idealistic and influential young deputy named Lakanal who was appointed by the Convention to receive the requests of the Academy. He not only received them; he acted

on them. He was the last real friend the Academy had in the Convention. To him Lavoisier wrote, "Never has the Academy been burdened with more numerous and important tasks. . . . These services are free to the nation, freely given by zealous members of the Academy. When these tasks are heaviest, funds upon which they depend must not fail. Citizen, time presses, academicians suffer, many have left Paris because their finances no longer permit living here. If the sciences are not supported they will rot and we cannot regenerate them."

Lakanal lost no time in appearing before the Committee of Public Instruction with his first request—that the Academy be permitted to fill vacancies. He had to face such men as David, the great painter, Arbogast, and Fourcroy, De Morveau, Grégoire and Sieyès. Surely a committee composed of such intelligent men would look with favor on the Academy. But no! Politics create strange contradictions. Grégoire was friendly but not powerful; Sieyès was losing his grip. David, Fourcroy, De Morveau ruled the committee. Even so, Lakanal won his point; the Academy might nominate for vacant places but the committee would do the electing.

Then came Grégoire's report on academies, given for the Committee on Public Instruction. Though the report condemned academies in general as decadent institutions of ancient and special privilege, it singled out the Academy of Science for more lenient treatment. "The Academy of Science," he wrote, "has always had as its members the first ranking scientists of Europe; it has published more than 400 books and 130 volumes of memoirs. We would be dishonored if our scientists were forced to go abroad with their talents. . . . *The sublime researches in chemistry have revolutionized that science* and presented to astonished Europe the only true theory of nature."

Here was a tribute both to the Academy and to Lavoisier, though there was no mention of Lavoisier's name. But even Grégoire knew that his appeal could not save the Academy of Science.

It was David, "the swoln cheek choking his words in birth," who finally demolished the academies one and all. Aimed particularly at the Academy of Painting, his blows fell with im-

partiality on all the ancient institutions. "In justice to art and for the love of youth let us wipe out these ugly academies which have no place under a free régime. Academicians, I have done my duty." He was right, the academies were relics of the Ancien Régime, they should give way to the new democracy.

But, he had done his duty too well. In crushing one, he crushed all. Grégoire, with the help of Lavoisier, had drawn up a scheme to save the important scientific work carried on by the Academy of Science. The Academy was to be abolished, and a new, more democratic society of science established in its place. But even this was to be denied. The excited Convention voted only on the first of the propositions, namely that "all Academies and literary societies patented and endowed by the nation are hereby suppressed."

It was the end. Surely Lavoisier would admit defeat now. But no. He writes to Delambre, at work in Amiens on the problem of mensuration, "The circumstances of suppression must not retard your work. The Committee on Public Instruction is concerned with means for seeing that it will not be interrupted."

On August 10, two days after suppression had been voted, the Academy held its last meeting. For the last time minutes were read, reports were heard. Each member placed a memoir on file, a memoir to appear in the last volume of the transactions; sad honor for the loyal few. Then the meeting adjourned.

Still Lavoisier fought on, seeking permission to form a free scientific society to carry on the work of the Academy. He wrote to Lakanal describing the last meeting and seeking aid in the new project. Once more Lakanal responded nobly. Passing by the Committee on Public Instruction this time, fearing there either slow action or an adverse decision, he appealed directly to the Convention and with surprising success. This Convention, like all other legislative bodies, could readily reverse itself. On August 14, it decreed that "the Academy of Science will continue to meet in the usual place and work with subjects already submitted or to be submitted by the Convention. Annual sums paid to scientists of the Academy will be paid as usual."

Success after defeat! On August 17, Lavoisier and his colleagues went once more to the Louvre to start again their labors for science and the nation. Full of high hopes for the future, gratitude to the Convention for its tardy recognition of their labors, these men came. However, they did not enter, for the quarters had been sealed by order of the Department of Paris in accordance with the decree of August 8. Lakanal had passed by the Committee of Public Instruction, and this was their answer. Fourcroy, David and De Morveau had won. The Department of Paris chose to recognize the decree of August 8 and ignore the later one. It may seem strange that the Department of Paris could ignore a decree of the National Convention. But the reins of national government had already passed from the legislative body to the great committees and to the city of Paris.

We see Lavoisier during these busy days in the pages of a letter written by young Du Pont to his wife on August 15: "Tell him [the elder Du Pont] I went yesterday to M. Lav at the reestablished Academy and gave him the letter papa sent for him. He said that he had been unable to write as he promised because, besides the fact that for several days he has been in the country, he has been kept very busy by the suppression of the Academy and his efforts to have it reestablished as it has been." The use of the title, M. Lav indicates the fact that Lavoisier was now under suspicion.

Lavoisier wrote his last letter to Lakanal on the subject of the defunct Academy: "Citizen, I have received with inexpressible gratitude the decree of August 14th which you sent me. Unfortunately, circumstances do not permit the use of the decree. . . . We cannot meet in free society without opposing the wishes of the Committee on Public Instruction and of the Assembly. The Academy is through, strangely enough at the moment when the Convention sanctioned its existence."

Though Fourcroy with the help of his colleagues had succeeded in demolishing the Academy, he had no intention of letting the important work on weights and measures drop. He wrote to Lavoisier brusquely demanding to know the present status of the work. Then he proposed a new commission to carry on the work, a commission supervised by himself and

Arbogast. The new commission on weights and measures began its work with all the former members in their respective positions. Once more Lavoisier took up his work as treasurer—working now under the scrutinizing eye of his former pupil, Fourcroy. For two short months he would hold this position as treasurer and virtual director of the commission. Fourcroy would move onward toward a post under the most powerful committee of the Revolution, the Committee of Public Safety.

While Lavoisier fought to save the Academy, France was being swept into the Reign of Terror. In spite of Danton's pleadings to forget quarrels and face the enemy, the Jacobins and Girondists continued their bitter feud. The Girondists threatened and talked, the Jacobins conspired and acted. In May 1793, a body of National Guards and armed ruffians appeared at the Tuileries, now the hall of the Convention, demanding expulsion of Girondist leaders. The demand was soon granted, leaving the Jacobins in complete control.

In two weeks a new constitution was drafted and accepted—but never put into effect. The nation was being ruled by the powerful Committee of Public Safety, the leadership of which was passing from Danton to Robespierre and St. Just. The important Committee of General Security had been created, as had the terrifying Revolutionary Tribunal. Tumbrils were beginning to roll through the streets of Paris, carrying groups of bound victims to the guillotine.

Why had the Terror come to France? Because the Jacobin leaders believed that only through such a drastic policy could the republic be saved from its enemies abroad and at home, because fervor, ardor and worship of the ideal of a Republic of Virtue required a concentration of will which would brook no opposition. "A single will is needed," wrote Robespierre, the incorruptible. But there never was a single will.

In July, the proud Norman girl, Charlotte Corday, arrived in Paris with her knife well whetted to end the tyranny of Marat. Suffering from skin disease, Marat found peace only in his bath, and there Charlotte Corday reached him to end forever his career of contrasts. Did Lavoisier breathe easier? As proudly as she had struck, this girl rode to her death on a day

when the black heavens shot forth jagged streaks, convinced that she had saved France.

In October, Marie Antoinette, now a prematurely aged woman, followed her husband to the guillotine. The widow Capet did not ride in a carriage as her husband had; she rode in a tumbril like any other victim. The streets were guarded by only thirty thousand troops, not one hundred thousand. But the guillotine was the same, the executioner the same, the death the same.

Next came the Girondist leaders, all that could be found, twenty-two of them. They sang as they rode to death, they cheered the republic. But they died just the same. Clavière was not among them; he preferred suicide. Malesherbes soon followed his master to the guillotine. Rochefoucauld, too, was dead, killed by a stone hurled through his coach window as he fled from Paris.

And by this time La Fayette is imprisoned in Austria. Condorcet, proscribed by the Jacobins, has fled. In the home of Madame Vernet he finds safe hiding while he writes his last great book on the *Progress of the Human Mind,* a book which shows all too clearly that even Terror cannot destroy his belief in the basic idealism of the free human mind. Then, he ventures forth in the disguise of a peasant. But his words and manners belie the disguise; he is arrested, thrown into prison and dies, perhaps of the poison he carries concealed in his ring. At least, he escapes the guillotine.

Bailly is in prison. His end is the cruellest of all. It comes on a cold rainy day in November when he rides through the streets, cursed, pelted with mud, mocked. He is to be executed on the Champ-de-Mars where he once ordered troops to attack the mob. But the crowd rebels. "Such blood ought not to stain an Altar of the Fatherland: not there; but on that dung-heap by the riverside!" The guillotine is taken down and carried to the riverside. Bailly waits in the rain. He shivers; he is taunted for cowardice. Cold death finally relieves his numbness. Thus ended the life of Lavoisier's friend, member of two great French Academies, historian of astronomy, once president of the Constituent Assembly, mayor of Paris, hero of the populace.

With grave misgivings, Lavoisier watches the storm clouds descending around him; the Academy is no more; his former disciples have deserted him; nay, more, have pointed him out as an enemy of the people by inference; former friends no longer gather around his table, to do so would incriminate them; Du Pont is in hiding, Bailly and Rochefoucauld are dead. Condorcet will soon die. The Convention is about to pass the Law of Suspects ordering the arrest of all who favor monarchy, who have not "manifested their attachment to the Revolution." It was high time for Lavoisier to flee the country but he stays on hoping to escape the fate of many of his friends, striving to become a good republican. Can his peerless work in science save him now?

Death of a Scientist

THE critical year of 1793 drew into its waning quarter—Antoine Lavoisier still lived, but the shadow of Terror was drawing closer. The farmers were again objects of attack.

"Why haven't the farmers settled their accounts as ordered?"

"Bring the bloodsuckers to justice," screamed the newspapers!

"Make them pay to the last penny—bleed them as they bled us," echoed the pamphlets.

"Citizen deputies, do your duty!"

For almost a year, now, the committee liquidating the affairs of the farm had been trying to finish up its work (or perhaps it was dawdling, hoping for a return of the old régime). The final report, due January 1, 1793, was still not in. The treasury needed money; pamphleteers were shouting that the farmers had defrauded the nation of four hundred million livres.

Mollien stated, with the assurance of intimacy, that the farmers did not, among them and including homes and lands, possess more than twenty millions; Clavière had praised the work of liquidation; but it made no difference. The bloodsuckers must be sucked clean, must disgorge, somehow, four hundred million. "Tremble, you who bled the poor and tricked beneficent kings. The judgment is at hand."

In June, deputy Mataunt, wrathful at the delay, had demanded that all funds of the farm be turned over to the National Treasury, all papers of the farm be sealed. Obedient to popular clamor, the Convention voted the decree. Helplessly the committee on liquidation waited, unable to proceed without its papers.

It was at this time that Lavoisier foresaw the loss of his fortune. All would go into the hands of the government. "He planned," said Lagrange, "to start over again as a pharmacist, a profession for which he was well equipped through training and experience."

In September came a further blow. The papers of the individual farmers were sealed. Even Lavoisier's laboratory was sealed against his use. What irony!

On September 10 came a most unusual pair of visitors to Lavoisier's home, Fourcroy and Romme. Was it a call of sympathy? Far from it. It was an official visit from representatives of the Committee of Public Instruction, a visit to search the premises for all papers pertaining to the work on weights and measures, to see that these papers were not sealed with those pertaining to the farm.

What a strange fate it was which sent Fourcroy, once a disciple of Lavoisier, now a powerful revolutionary agent, to inspect his home, to pry into private papers, to rummage through desks. Disciple had now become master; was he as generous in his new-found authority as the other master had been? Was there sympathy in his heart for the man whose home he searched? Austere official records tell us nothing. We know only that Fourcroy wrote a terse letter to Lavoisier demanding details of the progress of the work on weights and measures. We have no reason to assume that Fourcroy was animated by more than a sense of duty. Yet, there has lingered on the suspicion that something more lay back of Fourcroy's sudden coldness toward Lavoisier. Was it that he hoped to assume the mantle of leadership in the new chemistry, or was it that his supposed friendship with Lavoisier had in reality been a cloak for envy? The least that can be said is that Fourcroy was repaying Lavoisier's friendship and assistance in strange coin.

Did Fourcroy expect to find evidence which would stigmatize Lavoisier as a counter-revolutionary and thus bring him before the dreaded Tribunal? If so, he found none in the letters he carried away with him, letters from Black, Priestley, Watt, Wedgwood, and other distinguished scientists. On each of these letters Lavoisier insisted upon placing his personal seal. Who

knew but that incriminating documents might be inserted in these innocent writings?

By the end of September the seals were removed, Lavoisier exonerated. "Citizen," wrote the secretary of the section, Piques, in which Lavoisier's home was situated, "I hasten to send you the certificate authorizing the removal of the seals from your home. Everything there pays homage to your loyalty and removes all suspicion."

On November 14, 1793, deputy Bourdon shouted to the Convention: "This is the hundredth time that the affairs of the farm have been brought before us. I demand the arrest of these bloodsuckers, and, if their accounts are not in order in one month, I demand that they be turned over to the law of the nation." Withering away in the storm of uncertainty and contradiction, the Convention must obey every popular demand, follow every patriotic impulse, else it might lose its own head. It hastened to obey this popular demand. The arrest of the farmers was decreed.

Could Lavoisier, blameless in his personal life, tireless in energy for the welfare of his fellow-men, devoted to the honest service of his government—could this man escape the ignominy of arrest which faced his fellow farmers? Did his service to the nation count for nothing? Did his great contribution to pure science carry no meaning whatever to his countrymen? None! He was a farmer; that alone had meaning now.

Further, was he not ready to blow the Bastille to pieces in 1789? Marat had said so. Was he not guilty of providing the enemies of France with powder (was he not, too, the man who had given France her present stores of powder, the finest in the world)? Was he not guilty of corresponding with the royalist émigré, Blizard? Someone accused him of that. Was he not an '89er, a former academician, a constitutional monarchist? Was he not accused publicly before the Convention by former employees of the Powder Commission, by men who had failed of promotion because of his rigid honesty and justice? But this was not all. Was he not stricken from the list of charter members of the new Republican Society of Science, stricken off as a counter-revolutionary, a line passed boldly through his name

by the pen of Antoine Fourcroy the well-known patriot? It was enough. Lavoisier could expect no special consideration, no clemency. He was a farmer; he must fall with the farmers.

When word of the decree arresting the farmers reached Lavoisier he was on duty with the National Guards. There was yet time to escape. Stupidly, the officer seeking Lavoisier was directed to search for his victim at the Arsenal, a home which had not been Lavoisier's for more than a year. The decree even ordered the arrest of Baudon who had died twelve years before. Where could Lavoisier go? He dared not leave the city now. It was to humble Lucas, custodian of the former Academy quarters in the Louvre, that the fugitive turned. Patriot Lucas welcomed his former benefactor, sheltered him in his modest apartment next door to the Academy which had so often echoed to Lavoisier's voice.

From this strange shelter under the very nose of the Convention, Lavoisier penned two letters, letters which indicated his naïve confidence in justice. The first, written to the Convention, was sent on to the Committee on Public Instruction:

"Representatives of the People:

"Lavoisier of the late Academy of Science left the farm about three years ago. Called at that time to the post of Commissioner of the National Treasury, he contributed greatly to its organization. He is now National Commissioner of Weights and Measures. . . .

"It is well known that he has never concerned himself with the general affairs of the farm which were conducted by a small committee appointed by the minister, and, moreover, his works show that he has always been principally occupied in science. . . .

"He begs the National Convention to let him know if its intention is that he shall occupy himself with the accounts of the farm, a task which he does not think should be his, or if he is to continue to carry on his duties as Commissioner of Weights and Measures for which he has worked with zeal, and he dares say, with some success."

The letter lacks dignity. Lavoisier's statement that he never concerned himself with the "general affairs of the farm" is sur-

prising. Would he dare make the statement if it were untrue? Hardly. If true, it indicates that Lavoisier did not accept appointment to the administrative committee made by D'Ormesson, and probably opposed D'Ormesson's pillaging of the Discount Bank.

De Morveau, president at the moment of the Committee on Public Instruction, read this missive to his colleagues, Fourcroy, David, Romme, Argobast. Did they listen with sympathetic interest? Possibly. But there was no comment and the committee turned to other matters. There was no reply.

The second letter went to the powerful Committee on Public Safety. It was of similar tenor but carried the added request that its writer be allowed to continue his scientific work "at home in a state of arrest under the eye of two officers of the law . . . his person and all his wealth guarantee his moral and physical responsibility." This letter, likewise, brought no reply.

Two days later, fearing to compromise Lucas, his wife, his few remaining friends, and learning that Paulze had been arrested, Lavoisier left the Louvre, bade Marie farewell, and presented himself to the officers of the law. At the prison of Port Libre, he joined his father-in-law, Jacques Paulze, and the rest of the farmers, some thirty-two in number. On the prison register appeared the brief statement: "Lavoisier, former farmer—Motive, to straighten out accounts—by order of police." That was all.

The prison of Port Libre was crowded to capacity. Nuns, ladies of state, ex-royalists, counter-revolutionaries mingled in the courtyard with pickpockets, embezzlers, and republicans. But strangely enough in these days when all class distinction had been leveled off, the first floor was reserved for wealthy citizens, men and women of rank. Here it was that Lavoisier found his shelter, in cell 33, which he occupied with Jacques Paulze and Nicholas Deville. It was a large cell, as cells were counted, and what was most important, it had a stove, a rare luxury for any cell. The warmth of the stove soon drew others toward 33. Going to work with a saw, a hammer, and a few boards, Lavoisier soon had the place looking at least respectable. He wrote to Marie that he enjoyed his cell but was some-

what disturbed because it served as a headquarters for all the others.

Prison life in the days of the Terror was far from intolerable. In the evenings, men and women gathered in the large hall to chat, read, or play at cards; women knitted industriously or joined the men in their pastimes. Meals were good or bad according to the ability of the prisoner to pay. To avoid criticism the farmers ate very modestly.

Lavoisier was not the man to let time hang heavily on his hands even in prison. With nothing to do in the matter of liquidating the accounts of the farm, he turned his attention to scientific work, laboring industriously on the collation of his memoirs which were being published by Du Pont as his *Works of Chemistry*. He wrote to Marie, "I have begun to assume a type of life compatible with the circumstances. Yesterday, I worked two and a half hours in the afternoon on my memoirs."

But, for all of his air of lightness and confidence, Lavoisier was deeply concerned for his own safety and that of his colleagues. The others might hope that through Lavoisier they would all be saved. He had no such confidence. His misgivings were freely expressed to Marie in his letter of December 19, 1793.

"My Dear,

"You are passing through difficult times and are causing yourself much mental and physical anguish which I cannot share. Be careful of your health, its loss would be the greatest of misfortunes [no doubt he referred not to physical health but to the danger of arrest which hung perilously close to Mme. Lavoisier during these days]. My career has gone well. I have enjoyed a happy existence since I have found myself. You have contributed to it every day by the marks of endearment which you have given me. I shall always retain the memories of your esteem and consideration. My work is done. But you have a right to hope for a long life. Do not lavish it. Yesterday, I thought you seemed sad; why should you be so? I am resigned to my fate and consider that I can lose nothing that I have already gained. Besides, it is not utterly hopeless that we will

be reunited again. Meanwhile, your visits give me my happiest moments."

This was not the brilliant scientist or the successful financier writing, it was a man who had lived for many years with a woman whom he loved and respected. The hardness and coldness were gone—and never existed for this woman. Could it be aught else than the terrible blow she was soon to receive which would so alter the nature of this affectionate wife in the youthful prime of her life?

The elder Du Pont, in hiding at his estate, was deeply concerned over the plight of Lavoisier. There had already arisen some coolness between the families over financial matters as is indicated by the letter of Father Du Pont to his son on August 30, 1793: "In order to meet some of our obligations we would have to sell some of our lands, which is not easy, or again ask the help of friends who have grown cold, who already have too much capital in our hands. . . ." Again Du Pont refers to the unpleasant financial matters when he begs of his son, "Bring us money for payment on La Brosse; we had a letter yesterday, and they only give us a week."

In spite of these differences, Du Pont was seeking some way to help his friend. "I have not been able," wrote Irénée to his young wife on December 12, 1793, "to see the scientist of whom we talked the evening before I left; he is ill as we thought [meaning that he was in prison]. I am going to see his wife this morning. Faure, who has seen her, says that she is very well and assured him that her husband's condition is not alarming and that he will be quite well when he is thoroughly dosed." The dosing no doubt referred to the fact that the farmers expected to be stripped of their wealth, then set free. A few days later Irénée wrote again, "I saw the citizeness Lavo yesterday; she is very well, her husband neither worse nor better."

As the clouds of Terror dropped still lower around the Lavoisiers in January 1794, and even around Irénée du Pont, the correspondence became more concerned, and the language more veiled. The elder Du Pont became the "Doctor." "Our Doctor," writes young Mme. du Pont to her husband, "is very worried about the illness of citizeness Lavo and the condition of your

health and knowing both your constitutions [dangers hanging over them] is eager to leave everything here to go and give you his care and advice. . . ."

To this dangerous mission proposed by the elder Du Pont, Irénée replied, "As for what you say of the Doctor's journey, tell him it is forbidden by doctor's orders. He need not be worried—the Citizeness Lavo is very well; it is her husband who is ailing, but we hope that he will be better. Of course, we miss your doctor's care and advice, but we prefer to do without them rather than having him risk being ill—at a time when he is already far from well."

"My Doctor," replied Mme. du Pont, "insists on going with me [to Paris] even if he only stays a day to see for himself the symptoms of his friend's illness and to give one consultation, for his duties here will not permit a long absence—nor will his devotion allow him to be useless when his friend is suffering. He is much relieved that you give us better news of his illness, though it does not seem to take the usual course."

What did Du Pont do for his friend in Paris—what could he do? Denounced by the Assembly, subject to arrest on sight, proscribed from Paris as a noble, he could offer only sympathy.

Other attempts to free Lavoisier were equally hopeless. The Commission of Weights and Measures ventured a protest to the Committee on Public Safety asking that Lavoisier be given restricted freedom to continue his important work on the expansion of metals. The answer came two days later. Upon the advice of the Committee of Public Instruction, Lavoisier's name was stricken from the list of commissioners along with those of his friends Borda (who had sent the request), Laplace, Coulomb, Brisson and Delambre. Thus ended Lavoisier's association with this great project. Again Fourcroy had spoken; again De Morveau had voted.

A request from the committee on assignats fared little better. "Take," they asked, "such appropriate measures as necessary regarding the security of this citizen, but permit him to work in his laboratory. His labors are necessary for the standardization of the new issue of assignats which work is now suspended because of his arrest." The request went unheeded.

In late December the farmers left their prison at Port Libre for a new one, a strangely familiar one. The Hotel de la Ferme, with new bars on its windows, had been converted into a prison to house the farmers. Here the committee might once more work on the tedious process of liquidation. No beds awaited them in this new prison, no fires of welcome burned, no rich green carpets muffled their tread. Instead, bare walls, barred windows, guarded doors faced them. Many of the farmers, now penniless, had to borrow the five livres a day necessary for table expense. Nevertheless, they went happily to work. The job would soon be done, freedom assured.

Early in January came the next blow. All worldly goods of the farmers were placed under seal, pending settlement of the government's claims. Seals were placed on Lavoisier's home and laboratory once more. His estate at Fréchines was locked. Madame Lavoisier was forced to take refuge with friends.

But Lavoisier would have no further use for either laboratory or home. Only once more would he see this home—when he was brought from prison under guard of gendarmes to meet Fourcroy and De Morveau, once more to turn over to them all records and reports of the Commission of Weights and Measures. Three members of the famous quartet of "French Chemists" were together for the last time under these ironical circumstances. He who had been the leader was in chains: they who had been the followers were in power. What words were spoken we will never know.

By the end of January, the work of the liquidating committee was finally finished, the report was in. With lightened hearts, the farmers looked forward to eventual freedom. True, they might lose their fortunes but they would be free men once more.

Now came the turn of the revising committee, headed by deputy Dupin, once an employee of the farm. For two months this committee audited, revised, discovered while the farmers waited impatiently. Then came the staggering report: The farm had embezzled one hundred thirty million livres. It was a far cry from four hundred million but enough to satisfy the popular clamor.

Indignantly, the farmers drew up a document denying these charges, a document edited by Lavoisier. True, water had been added to the tobacco. Lavoisier had drawn attention to that fact as early as 1778 when he wrote concerning tobacco from the station of Morlix, "I fear that the tobacco is soaked too much. It is better to be conservative in the soaking, to make lighter profits than to dissatisfy the people." His words had their effect; in 1786 the percentage of water was drastically reduced. Cadet and Baumé had studied the problem long ago for the state; they knew of Lavoisier's stand in the matter and were ready to present their evidence. It was a generous action on the part of Baumé, ardent opponent of Lavoisier's oxygen theory.

According to the revising committee, the farm had made a sheer profit of thirty million on excess water in tobacco alone—fourteen pounds in every hundredweight was the claim. Lavoisier showed the absurdity of the charge. It was necessary to add water in the processing of tobacco but to compensate for this the farm deducted six per cent from the weight of the delivered product in determining its charges. After 1786, the standard quality of tobacco contained a minimum of water, two and a half per cent—a far cry from the fourteen per cent claimed.

Figures lie; Dupin's one hundred thirty million livres were no exception. When the final accounting was made, it was discovered that instead of one hundred thirty millions, the actual amount was eight millions; instead of being owed to the state, it was owed to the *farm*. But this accounting came too late.

Right or wrong, honest or dishonest, the farmers *must* be punished. Pay one hundred thirty million? They never could for the simple reason that they hadn't that much among all of them. But they could and would be forced to pay all that they had, all their worldly goods. To those farmers who favored voluntarily turning over all their wealth to the state, Lavoisier replied, "Let them take it if they will, to give it would be but to admit guilt." There was no criminal charge against the farmers. Only acts against the Revolution were punishable by death. The farm as a body had committed no such act. Had not Dupin given his word that the farmers would soon be free?

Yes, Dupin had given his word, but few believed it. The tide of Terror was rising to its greatest height. Danton had already gone to the guillotine with Camille Desmoulins, and Hérault de Séchelles. What hope was there for the bloodsuckers to escape a similar fate? Criminal charges could be found when the time came.

Now Lavoisier began his last hopeless attempt to regain his freedom. He wrote to the Bureau of Arts and Crafts, the only public body from which the hand of Fourcroy and his colleagues had not yet snatched him, asking for a certificate showing his service to that body. "I ask," he wrote, "only a statement of facts. Please avoid anything which might have the appearance of a friendly feeling or of the confidence you have so often shown in me."

The Bureau readily acquiesced, drew up a report edited by Borda and Citizen Hallé. Though the report was not ardent in its praise of Lavoisier, it was, nevertheless, a fair statement of fact and a courageous document in the face of the well-known attitude of the Committee of Public Instruction toward Lavoisier.

Two members of the Powder Commission made a half-hearted attempt to save Lavoisier by reminding the Committee of Public Safety that he was still under order to prepare the final accounting of the former Powder Commission. Cadet and Baumé came forward with a statement concerning Lavoisier's stand on tobacco. That was all—all that came from former colleagues and influential friends who had sat at his table. It was all that could be expected; most of his friends were dead, in prison, or turned enemies. Finally, Lavoisier, himself, drew up a brief autobiography detailing his work in various fields of public service.

Two other loyal supporters were, however, still working for him. Marie Lavoisier, herself a fugitive, in hiding with a faithful servant, was still clinging to hope, a hope growing more forlorn with the passing of days. Pluvinet, the druggist, old friend of Lavoisier, too obscure to be in danger, was using his little influence to save his friend and patron. With courage and cleverness, Pluvinet attempted to secure the transfer of Lavoisier

to another prison. Once separated from his fellow farmers, he could be easily overlooked, as were others, when the day of judgment came. Through a sister-in-law of Dupin, a woman of not too savory reputation, Pluvinet reached the important deputy. Nor did Dupin decline to listen to the plea.

Yes, Dupin might engineer the transfer—provided that Madame Lavoisier came in person to request it. Here was a chance to save Lavoisier, a bare chance, to be sure, but one well worth taking. But in what a sad dilemma it placed this unfortunate woman. To ask for her husband's transfer would be to leave her father to cruel fate alone. To ask for the transfer of both would be to be denied either. Was there no way of saving both her father and her husband?

She went to Dupin, but not in humility, not to plead. He who expected a cringing, pitiful woman begging for the life of a loved one, saw instead one proud and haughty, flashing anger from a pair of fearless blue eyes. "I do not come to plead for my husband, for he is innocent—none but the basest could accuse him. Were he to separate his cause from the rest, he would be dishonored. They are all innocent—all. Bitterness against them comes merely from the fact that they were wealthy. If they die, they die innocent men!"

Marie's just anger, her righteous indignation, her attempt to save both husband and father had failed. And because of her own words, Antoine Lavoisier would die. "She sent her husband to his death"—this was the answer hurled at her when, in later years, she accused his colleagues in science of permitting murder by their silence. She said too much; they said too little. It is not difficult to excuse her anger; it *is* difficult to excuse their silence.

On Monday, May 5, 1794, Dupin presented the final report of the revising committee. Dupin, who had promised the farmers freedom once their accounting was in and their debt paid, now sealed their doom. "I demand," he said, "the restitution of twenty-two million livres. *I demand that the farmers be brought to judgment before the Revolutionary Tribunal.* Let the Tribunal distinguish between them if it can." Once before the

dreaded Tribunal few men ever escaped the guillotine. The decree was passed with no dissenting vote.

Lavoisier, standing in the courtyard of the farm prison, was the first to receive the news. It became his cruel duty to inform the others that the end had come. Life's span for the farmers was now a matter of hours. Private papers were burned, letters written to loved ones whom these men would not see again. Now the prison was closed to all visitors.

Mollien, under arrest with the farmers, and Taverner de Bologne favored suicide. From this course, Lavoisier dissuaded them, thus saving Mollien's life, for he was not brought to trial with the farmers.

"Why go out to meet death," argued Lavoisier. "Is it because it is shameful to receive it at the hand of another even when it is unjust? The very excess of injustice effaces all shame. . . . Our real judges are not in the Tribunal to which we go, nor among the populace which insults us. . . . Let us leave behind an example for those who follow." Thus wrote Mollien of Lavoisier's courage.

The prisoners were now transferred to the dim Conciergerie, last stopping place on the way to the scaffold. In the rumbling tumbrils, four to a wagon, they rode. It was their last ride but one. It was night; torches lighted the way. Here and there groups of *sansculottes* taunted them. Who are these prisoners? Oh yes, the bloodsuckers. Bad luck to them on the morrow.

Lavoisier shared a cell with Paulze and Delahante. It was the room Marie Antoinette had once occupied. It was the time for last letters. He did not write to Marie; she was still unaware of his fate and he did not wish to alarm her. He wrote to his cousin, Augez de Villers, "I have had a fairly long career, and above all, a happy one and I believe that my memory will be accompanied by some regrets, perhaps by some glory. What more could one wish? This affair will probably save me the inconvenience of old age. I shall die in good health which is an advantage to add to the others I have enjoyed. My chief regret is that I am unable to do more for my family, now that I am stripped of everything and that I can give you no tokens of affection and gratitude.

"It is unfortunately true that social virtues, important services to country, a useful life employed in the interests of the arts and human knowledge cannot preserve me from this dismal end; I must perish as a guilty person.

"I write today, for tomorrow I may not be allowed to do so and because there is consolation in thinking of you and those who are dear to me in these last moments. Remember me to those who love me to whom this letter is written in common. It is probably the last I shall write."

No bitterness, no recriminations against colleagues, no frantic resistance, no fear—only calmness, the ability even to joke about the inconvenience of old age; resignation, tinged with justifiable pride in a life well lived. Was this justice? In the view of contemporary France, yes! Lavoisier, in spite of all else, was a farmer. In the view of historical perspective, no! Lavoisier was the greatest scientist of his century. His life, his work in science belonged rightfully to the world, not France alone.

Another night passed. In the morning came the dread summons to the preliminary examination. The machinery of the Tribunal had started to turn. Lavoisier was searched, then, conducted before judge Dobson for formal identification. Was he Antoine Lavoisier, aged 50, born in Paris, farmer, member of the former Academy of Science, living on the Boulevard Madeleine, section Piques?

He was!

Was he guilty of juggling the finances of the government, of the exaction of unjust taxes, of watering tobacco and thus betraying the people?

He was not! He could prove with witnesses that he had recommended reducing the amount of water in tobacco.

Had he a defense counsel?

He had not! He knew of no one who dared defend him.

The court would appoint a counsel to defend him. The formality was over.

Back in the Conciergerie again, the farmers, stripped of all their money, all their possessions, including "a silver watch—the property of Lavoisier," could buy not even a bit of bread.

But some kind anonymous friend had seen to it that they would enjoy one good last meal. There was wine, meat and bread in abundance for all.

One empty honor, one last mark of esteem from a brave group unafraid of public opinion came unexpectedly to Lavoisier as he spent his last day in the old prison. The Lycée des Arts, founded in 1793, and of which Lavoisier was a charter member, sent a deputation to the Conciergerie to crown its illustrious member with a wreath. Strange action, this crowning of a man about to be executed—bold action. So quietly was it done that the act was all but forgotten. It stands, however, in the records of the Lycée "brought to Lavoisier in irons, the consolation of friendship . . . to crown the head about to go under the axe." Said Lakanal later, "When the blood of the innocent flowed in unchecked torrents, it dared remind humanity that it had a heart, it publicly consoled and adopted the children of its victims, it crowned Lavoisier in irons. . . ."

It was only a gesture but it must have helped to sooth a heart sorely tried by the injustice of fellow-men, helped to ease the long hours of that last night, helped to face the morrow with the confidence that not all men had forgotten him.

At one o'clock in the morning of May 8, the farmers were aroused from their fitful slumbers. Each was handed a copy of the accusation, an accusation prepared by the public prosecutor, Foquier-Tinville, even before the decree had passed the Convention. For this very haste, Foquier-Tinville himself would soon go to the guillotine.

At dawn, they were aroused and searched once more. They would have fifteen minutes before the trial in which to confer with counsel for the defense. Fifteen minutes! Why waste precious minutes in such useless conference? Since Lavoisier's counsel failed to arrive, he was spared this waste of time.

At ten o'clock, the judges of the Tribunal entered the crowded courtroom. Then came the accused, "free and unfettered," thirty-one in number. But three of these would escape the penalty of death. Young judge Coffinhal, who would appear, a doomed prisoner, before this same bar in a few months, was in the presiding judge's chair. Lienden, understudy to

Foquier-Tinville, was in place as public accuser. On the jury sat an ex-marquis, a wig-maker, a jeweler, a vinegar-maker, a cabdriver, and others. There were the defense counsel, only four in number, to defend thirty-one.

The usual muttering throng was there to witness the bleeding of the bloodsuckers. Needles of the knitting women clacked forebodingly. For the *sansculottes,* it was a gleeful day. Yet, there were those who pitied these unfortunates.

An hour and a half were spent in preliminary questions. Some of the answers evoked derisive laughter from judge and jury. To get on with the trial, all details were omitted and personal defense was forbidden. Then, suddenly came a reprieve to three prisoners. Delahante, Sanlot and Bellefaye were released through the intervention of judge Dobson, a relative of Delahante. They were only assistants, had never signed a farmer's lease—that was the technicality. Lucky men!

The trial went on. With little interest the prisoners listened to the charges, to the oratory of Lieden, to the feeble attempts at defense. Brave Citizen Hallé presented the report of the Bureau of Arts and Crafts in defense of Lavoisier. Coffinhal glanced at it; then came the long remembered and oft quoted words: "The Republic has no need for scientists; let justice take its course."

Did Coffinhal really utter these words or are they a figment of some writer's imagination? Some historians say he did; others say not. But whether he did or not makes little difference; the words are characteristic of the demagoguery of the times. The Revolution did not renounce science, it merely failed to distinguish Lavoisier, the farmer, from Lavoisier, the scientist; it could not convict the one without the other, save the one without the other.

Did Lavoisier beg "a fortnight more of life, to finish some experiments"? Carlyle says he did. But Lavoisier had no experiments to finish. If there were experiments to be done they were not his own but those for the good of the nation. Other men could carry on such work. No, Lavoisier begged no stay of execution, asked no special privilege now to finish his experiments. He was given no opportunity to do so. His life's work

was done, his contributions made. Ten more years might have added untold wealth to his contributions in science, advanced the progress of organic chemistry, of physiology, by more than a generation, but a fortnight could add nothing.

Now, came Coffinhal's charge to the jury. Shrewd Coffinhal must make it clear that these farmers had plotted against the welfare of the Republic, else they must go free. There must be no mistake about it—a plot existed against the Republic of France—even though the farm ceased to exist three years before the Republic was founded. "Has there existed," he queried, "a plot against the people tending to favor the enemies of France by excising, extorting, exacting from the people, by adding water to tobacco and making it injurious to citizens . . . by retarding the warfare of the nation against despots who rise against the Republic?"

Yes, Coffinhal had found it possible to add charges not even in the original accusation. There *was* a plot against the people of France. "Guilty as charged," came the unanimous and expected verdict.

In less than four hours twenty-eight men had been examined, tried, and sentenced. So fast did this court roll out its victims, so great was the press of waiting cases that the clerk failed to inscribe the verdict of the jury on the record. But that made little difference. All possessions of the condemned men were declared confiscated to the nation. Execution would take place within twenty-four hours. The court moved on to its next victims. The prisoners returned to the Conciergerie.

By five o'clock the tumbrils drawn by weary horses were at the gate. Dressed in shirts open at the neck, with hair clipped short in back to make the work of the knife easy, with hands tied behind them, twenty-eight men entered the crude death-carts. In one, stood Jacques Paulze and Antoine Lavoisier, still together, comrades to the last.

It is a short trip from the Conciergerie to the Place de la Revolution but the carts move slowly. Past the Louvre where Lavoisier gazes his last at the windows of the old Academy, down the Rue St. Honoré, past the Tuileries they go. Crowds

gather as the somber wheels move on. Though the sight of loaded tumbrils is no longer a novelty for them, they are curious. Who are these, on their last slow ride? They are the bloodsuckers of the people. Where now are their gilded chariots, their purple robes, their supercilious airs? Who is that man with the fine high forehead, the graying hair, the straight aquiline nose, the calm gray eyes supporting his older comrade? Only another *fermier*. Then Papillon d'Hauteroche speaks his oft-remembered words as he passes a crowd of noisy revellers, "What hurts me most is to have such unpleasant heirs." Sanson silently escorts his victims.

Around the guillotine is the same restless inquisitive throng watching the monotonous spectacle. The sun hangs low in the west on this clear day of May 8, 1794. One by one the victims dismount. Many onlookers hurl taunts at them; a few, pity them.

On the platform stands Sanson, he who has executed king and queen, prince and lord. Does he know now that he is about to execute one as great as any of them, one who is, himself, the leader of a profound revolution? He knows only that these are the farmers of the taxes, justly condemned.

First to mount the steps to the platform is Clément Delaage; then comes Danger-Bagneaux. Jacques Paulze follows. The aging father of Marie Lavoisier goes to his death without a tremor. For six months he has leaned on the moral and physical support of his sturdy son-in-law. Now he must go alone. He goes bravely.

Lavoisier is next. He steps forward, unafraid, untormented by regrets, sure of the immortality of his memory. Men may die, revolutions may kill, governments may change, but his work will survive. He kneels to the inevitable. The hand of Sanson is lowered once more. Into the basket, above that of Jacques Paulze, falls the head of Antoine Lavoisier. Few in the gaping crowd realize that the guillotine has just claimed one of its greatest victims.

"At the square of the Revolution where on a scaffold set up on said square, said Lavoisier, in our presence, has undergone

the penalty of death," thus reads the only official obituary, the report of the delegated witness.

In a few more moments, tumbrils are loaded again, this time with a confusion of dripping heads and torsos. Off to the Madeleine cemetery they roll to empty their loads into a common trench. In death, Lavoisier is a farmer, buried with twenty-seven others. Justice could make no distinction; he had chosen this path knowing its iniquities.

On the morrow came the "obituaries" in the newspapers. "The red blood of the bloodsuckers is far harder now than the purple of their downy beds of a former day." Was Lavoisier singled out for more generous treatment? Who would dare?

Lavoisier's real obituary was spoken in the famous words of Lagrange when he was informed of the tragedy: "It took only a moment to sever that head but France will not produce another like it in a century."

Heritage

WAS Marie Lavoisier kept in blessed ignorance of the deaths of her husband and father on May the eighth? Merely a surprising missive remains to suggest that she did not know that the end had come. "Harmand," wrote Irénée du Pont to his wife, on the day after the execution, "went yesterday to see Citizeness Lavo. She is well and *not alarmed.*" Marie did not know that her husband was dead! But she could not be kept long in the dark. She must learn the heartbreaking truth soon; the death of the farmers was trumpeted in the news.

Alone in the world (her brother Christian had died a few months earlier), stripped of her wealth, a suspect in danger of arrest at any moment, in hiding with faithful servants, still she must struggle on. Even her dowry must go to satisfy the state; for the confiscation of the wealth of the farmers had far from satisfied the supposed debt to the state. The property of widows and heirs must go too. Dupin would wring the last sou from his victims. How they could pay was no responsibility of his.

To the offices of the Committee of Public Safety and the Committee of Public Instruction went Lavoisier's fine furniture; to government officials went his splendid Berline; to the city of Blois went his crop at Fréchines; to schools and museums went his valuable collection of laboratory equipment and minerals. Some, to be sure, experienced a feeling of revulsion in this disposition of the tools of the master. St. Hilaire wrote to Mme. Lavoisier, "Citizeness, by decree of the Convention the laboratory of our late regretted and unfortunate master has been turned over to three national institutions. I am charged by my colleagues with the painful duty of accepting the shares

granted to them. The remembrance of the virtues and talents of a great man whom we have lost is present in my mind when I consent not without repugnance to perform this unpleasant task."

Toward the end of May, Marie was prevailed upon to leave the memory of Paris behind her for a brief moment. Again it was the Du Ponts who came to her rescue. Wrote Irénée on May 24, "Yesterday, I saw the Citizeness Poivre and her daughter; I have also seen Citizeness Lav several times, she was good enough to come to see me since I could not go to her. I will probably see her again when I return and shall probably bring her home with me. Have a room ready for her to stay several days." To the scenes she had visited so often with her husband, Marie went, alone, seeking the strength of friends.

But she was back in Paris again by June 14, for on that day she was arrested by order of the Committee of General Security. She was a suspect. It was not enough that her husband had paid his life for their wealth, their title which they never used. "The Citizeness of whom our good friend seeks news," wrote Irénée on July 10, "has been very ill. Faure goes often to see her, and we hope that she will be quite well in a few days."

On the same day, the elder Du Pont wrote anxiously, "You give us news of one of the women I admire (Citizeness Poivre) but none of her who most interests my intelligence, my chivalry and my heart." Again, a few days later, comes the request, "Do not leave us in ignorance of the plans of my great friend. Love to Harmand, Faure, and by him to the Citizeness."

Was Du Pont's interest limited to the welfare of the unfortunate widow of his great friend or was he also interested in a brilliant, intelligent, charming woman? It was, indeed, a strange sort of courtship which was developing between a man in hiding and a woman in prison.

Soon, the rôles were to be reversed. Early in August, the elder Du Pont was apprehended, arrested, and thrown into the La Force Prison. Since his correspondence could be only with relatives, Madame Lavoisier became his "cousin who lives on the boulevard." On August 3, he wrote to his son, "Tell the Citizen [jailor] whether the news you sent me related to my

cousin who lives on the Boulevard. For news of her is what I most want." Again, "The Citizen has forgotten whether the lady whom you saw and who is well is my cousin who lives on the Boulevard and who lately came to Bois-des-Fossés. Tell him—and me—again."

On July 28, Robespierre was executed. The Reign of Terror was coming to an end. Du Pont, encouraged, wrote on August 8, "I do not believe that I will be free in less than a fortnight—though I expect freedom as confidently as a fortnight ago I expected death. But I am looking forward to two or three days in Paris, to seeing my friends and relatives and my cousin who lives on the Boulevard."

Was Marie, then, out of prison? Grimaux says she was not released till August 17. On August 12, Du Pont wrote, "Give many messages to my cousin—thanks to whom I have put on papers those wise, strong, and pious thoughts. [He was working on the preface of his *Philosophie de l'Univers*, which he dedicated to the memory of his friend, Antoine Lavoisier.] I do not wish either to tire or distress her, but she knows what I think and what I feel for her."

Three days later the clouds dropped once more over Du Pont when he refused to accept special consideration at the hands of the Court, preferring to stand with other ex-nobles and take his chances. "I want you, the Citizeness Lavo, everyone who has loved or esteemed me to be proud of me to the end," he wrote. On the same day, he wrote to Marie. What he said in that letter is not known but its contents are suggested by what he wrote to his son. "Please be careful to seal my letter to the Citizeness Lavo. . . . You know that I am not fond of many people but very fond of a few." Did she reply to his missive? Probably not, for he wrote soon after, "Many very affectionate messages to my cousin of the Boulevard whom I dare not bother with letters though I really want to write often."

What events had happened to cause Du Pont to write the following letter on August 23? We do not know; we know only that this strange courtship was going badly. "Answer my questions about our cousin. Was she really arrested or threatened? If the first, how did you see her? As for the justice done her, I

am not surprised, and I hope for more for her. You know she has given, gives, and will give me many moments of unhappiness. She has so many virtues, so much intelligence, and ability that she has a place in my heart even with you my dearest child. So that everything that concerns her interests me more than I can tell you."

Why was Madame Lavoisier in danger of arrest again? What was the cause of these moments of unhappiness? Was Marie, in desperate financial straits, demanding payments on the loan? Was she suspicious that this old friend, turned suitor, was wooing her to cancel a debt? No answers to these questions are forthcoming from documentary evidence. Only conjecture is left. Marie Lavoisier was poor, penniless. Du Pont was in worse straits; he was heavily in debt to the woman he was wooing, a debt, however, which, were it to be paid, would be immediately forfeited to the government. Where, then, is a financial motive? No, Du Pont's affections for Madame Lavoisier were undoubtedly genuine. He admired this woman greatly, sought to marry her, but she, in her deep distress, would not have him.

In September, this unique courtship came to an abrupt end. Why, we do not know. Du Pont, now out of prison, wrote in a bitter yet sympathetic tone, "Your affection . . . your caresses, my dear children, soothe my grief but cannot remove it. She has embittered my life. I owe her, we all owe her, all we can do for her. It seems impossible to give her my friendship again, and it was my delight to give her unreserved affection. I wish I could forget her. But her husband, who was my friend, entrusted her to my care when he was about to die and long before his death."

One year later Pierre du Pont married the Citizeness Poivre, widow of his old-time friend, Pierre Poivre. What had Marie Lavoisier done to embitter her good friend? Had she accused him as she did men of science, of permitting her husband to go to his death through silence? Surely she knew that, in his position, he dared not speak. Did she accuse him of attempting to marry her in order to cancel a debt? Possibly. But payment of the debt would merely mean more money to her enemy the state.

The probable truth is that the Marie Lavoisier whom Du Pont had known was dead; killed by the same blade which killed her father and husband. In Marie's place was Madame Lavoisier, cold, proud, haughty, who hid from the world the spirit that had died within her.

The Reign of Terror was over. Bands of young royalists and anti-Jacobins armed with leaded sticks took up "the Chase of the Jacobins." Back to their seats in the Convention came the Girondists—those of them who had escaped the guillotine by hiding. Back, too, came the freedom of the press, and freedom to worship. The brief era of the directorate was at hand to be followed by the Little Corsican, his new nobility, his far-reaching empire.

By December 1794 the reaction against the execution of the farmers had set in. Further confiscation of their property was suspended. Dupin, "murderer of the farmers," began to tremble. In vain did he attempt to place the blame on Robespierre. With an eye to safety, he proposed, in May 1795, that the confiscated wealth of the farmers be restored. In July appeared a pamphlet, edited probably by Madame Lavoisier, violently attacking Dupin and the judgment against the farmers. Newspapers took up the cry. Dupin found himself in prison. Set free after the general amnesty of October, he returned to the obscurity from whence he came. He who was responsible for the death of Antoine Lavoisier, lived on in peace, the peace of national sanity. By 1796, Madame Lavoisier, heir to the returned fortunes of both her husband and her father, was one of the wealthiest widows in Paris.

Her first act was to reward two faithful servants, servants who in time of Terror had sheltered her at the risk of their lives, fed her and even clothed her. Then she started bravely to finish the project her husband had started, the publication of his works of chemistry, based on memoirs read to the Academy during twenty years. To her husband's assistant and collaborator in his last years of private experimentation, Séguin, she turned for advice and assistance. She wanted him to write a preface, which would condemn the men of science who had raised no voice to save her husband. She would never forget

her bitterness against such men as Fourcroy, De Morveau, Hassenfratz, Monge, Arbogast, men who, had they spoken, would have been heard with respect. Séguin refused the task indignantly. "To turn against those men who condemned him does not please me;" he said, "it would diminish the horror that the event has left on all hearts. There are things better left unsaid, things that can be better said through the conscience. . . . If you are not of this opinion you may voice your own complaints; from you they might take on a meaningful tone." Séguin was right, such a preface would not have been in keeping with the changed times. Madame Lavoisier dropped the whole project.

Years later she took it up again, writing her own preface but making no statements of condemnation. Time had not softened her heart but it had guided her pen into less bitter lines.

"In 1792," she wrote, "Lavoisier conceived the idea of publishing his collected works. . . . In a way it was the history of modern chemistry. . . . This collection was to number about eight volumes. All Europe knows why they were never completed. . . . We beg indulgence for the mistakes that may have been made in other parts of this collection. All will surely grant this request when it is known that most of the proofs were reviewed in the author's last moments, and that, though he did not ignore the fact that his murder was premeditated, M. Lavoisier, calm and courageous, compiling a work which he hoped would be useful to science, gave a memorable example of the serenity which intellectual purity and virtue can produce in the most trying hours."

In thanking Madame Lavoisier for a copy of these fragmentary works, young Cuvier, who was soon to become one of France's greatest zoologists, director of education under Napoleon, peer of the realm under Louis-Philippe, wrote, "All friends of science owe you a debt of gratitude for the sad task you had of publishing the collection in its fragmentary parts. It is a sad monument to your loss and ours. . . . How many truths were we still to learn in a work which began with new truths; and how we feel again in all its force the horror of the crime which has deprived humanity for centuries."

In the lavish, popular salon of Madame Lavoisier on the Rue D'Anjou-St. Honoré gathered the men of science as of yore. But some of the old faces were gone. There was no host to discuss new theories of chemistry, art, politics, economics. Bailly was dead; Condorcet was dead; Malesherbes, Rochefoucauld and other liberal nobles were dead, victims of the past. Nor were Fourcroy, De Morveau, Hassenfratz, Monge to be seen there. They lived, but not for Mme. Lavoisier. Du Pont, too, was absent.

Still, there were some old faces to be seen among the newer ones. Laplace was welcomed, so, too, were Lagrange, Berthollet, and Delambre. They held warm places, honored places; they, too, had been suspects, hunted men. Their silence could be understood.

Of new faces there were those of Cuvier, Arago, astronomer and statesman; Biot, physicist, astronomer, Commander of the Légion d'Honneur; Humboldt, great scientist from Germany; Count Rumford, born Benjamin Thompson of Massachusetts.

There were others, titled Englishmen and those of the new French nobility. Sir Charles Blagden, secretary of the Royal Society of London, he who had charged Lavoisier with scientific plagiarism, came now to pay open court to the fascinating widow just reaching her mature years. Perhaps he was fortunate that his court was denied; perhaps he thought he saw in this woman the image of the enthusiastic young wife he had known in former years. To cold Madame Lavoisier, he remained only a friend.

"No event, no incident longer disturbed Madame Lavoisier in her noble and agreeable manner of living. She belonged to her friends and to society. She received guests with a singular mixture of coldness and politeness. She was always pleasant company, intelligent with brusqueness and a trace of authority." So wrote Guizot in describing the shell of a woman who once lived.

She was, however, to have a brief episode to disturb her dignity and repose. The charm, scientific ability and elegance of Count Rumford attracted her strongly. Born in far-off Massachusetts, young Benjamin Thompson had rebelled against re-

bellion, joined forces with the British army, fought against his native land, risen to the rank of lieutenant colonel. With victory for the colonies came exile for young Thompson. Leaving wife and baby girl behind, he moved on to England, to Bavaria, there to become the important aide of the Elector Charles George, and to receive for his valuable services the title of Count Rumford. Interested always in science, he turned his clear mind to many of the problems confronting physics. Curiously enough, he solved the one puzzle over which Lavoisier had always stumbled, the nature of heat; it was not a material caloric, it was a form of energy. It was this stranger, this genius so like her husband in versatility and in interests, who captured the imagination of brilliant Madame Lavoisier. Rumford's former wife had died; his daughter, almost a stranger to him, was a grown woman.

In 1804, Madame Lavoisier and Count Rumford were married, she retaining the name of Lavoisier. From the start, it was a marriage destined to failure. She found in this man not a model of her former husband, not a happy collaborator in science. At times he was morose, at times violent. She, in her turn, was not the companion for this man; she lived for social homage, needed the presence of friends. The Count locked out her guests; she poured boiling water over his flowers—so the gossip of the times would have it. Soon, they agreed to go their separate ways, remaining friends, but living apart.

Till her death, at the advanced age of seventy-eight, Madame Lavoisier remained a proud woman receiving the homage of men, surrounded by friends, but always alone with her past, a past in which she had lived and moved not as an empty shell but as a woman filled with love and affection, joy and happy energy.

The execution of Lavoisier had stunned the world of science outside of France, even as it stunned many in France. But, perforce it must pass unnoticed at the moment. Terror still ruled the nation. Even so, it must be granted that Lavoisier's genius in science, the significance of his new chemistry, had hardly been recognized by the world, so short was the interval

between its publication in final form and the death of its founder. The lapse of time has given us a perspective to see what his executioners could not hope to see, that his contributions to science far more than atone for his connection with the farm.

Not till 1795 was it safe to praise Lavoisier in his native land. In October of that year came the first memorial service. The Lycée des Arts had crowned Lavoisier in prison. Now it held his funeral service with Lagrange delivering the eulogy. A bust of Lavoisier bore the inscription, "Victim of tyranny, respected friend of the arts, he continues to live; through genius he still serves humanity."

A year later came a second service by the same Lycée. It was lavish, costly, overdone, in keeping with the times, but not with the memory of the man it sought to honor. Three thousand crowded the black-draped funeral hall to see the bust of Lavoisier raised on high from the grave of obscurity, crowned with the wreath of genius, to listen while white robed maidens and black gowned men chanted the praises of the master.

> "Let us remember the benefactions of talent,
> Let us open the pages of history to Lavoisier,
> Let us consecrate his genius forever,
> With a monument fitting his memory."

Strangest of all was the orator chosen to deliver the eulogy. It was Antoine Fourcroy, no longer an agent of the vengeful Committee of Public Safety but a member of the Council of Ancients. Why was he, of all men, chosen for this honor?

It is by no means certain that Fourcroy has always been given a fair hearing in the pages of history. Certainly there were accusations against him. A pamphlet accusing him of not saving Lavoisier from the guillotine was distributed near the hall where he lectured shortly after the Revolution. Robison accuses not Fourcroy alone but the "men," meaning Fourcroy, De Morveau and others, who sacrificed Lavoisier to their own ambition. Mme. Lavoisier was bitter against these men. It is said that on the tenth anniversary of Lavoisier's death, Napoleon attended a lecture given by Fourcroy—on whom he later

conferred the title of count. When the lecturer uttered the words, "The memory of Lavoisier will endure forever; may a lasting reproach rest on those who brought him to the scaffold," Napoleon is supposed to have cried out: "It was he who did this," pointing at Fourcroy and holding up a paper signed by Robespierre, Fourcroy and others.

These accusations may be dismissed as being without documentary proof. Napoleon's paper, if indeed this incredible story is true, might have been any one of many documents issued by the Committee of Public Safety or the Committee on Public Instruction. The author of the scurrilous pamphlet had been dismissed from his position by Fourcroy earlier; he was later convicted of slander against another. Robison's evidence is second-hand gossip. Mme. Lavoisier's reaction is that to be expected.

It is certain that Fourcroy was ambitious. Upon the death of Lavoisier, he might hope to become the leader of the "French Chemists." This, however, is a weak motive for plotting Lavoisier's death. Fourcroy had passed on to work in the Revolution which, to him, was undoubtedly far more important at the time than chemistry. It is likely that he gave little thought to either the "French Chemists" or the new theory during this troubled period. True, his statement that this theory was the theory of the "French Chemists" was an apparent attempt to rob Lavoisier of his glory. Fourcroy's excuse was that he hoped, thereby, to gain greater support for it. At any rate, Fourcroy made ample restitution in later years by calling it the magnificent theory of Lavoisier. The motive of personal ambition cannot be eliminated, neither can it carry much weight.

It is a reasonable assumption that Fourcroy honestly regarded Lavoisier as a counter-revolutionary, a recipient of favors under the old régime who had no place in the new. But this does not accord with his great profession of friendship. "I am accused of Lavoisier's death," said Fourcroy, "I, his friend, the companion of his labors, his collaborator in the modern chemistry, his constant admirer as may be seen in all that I wrote before and after the Revolution." What about the

period *of* the Revolution which Fourcroy significantly, or casually, does not mention. Were his feelings different then? He certainly professed little friendship during troubled days when he had Lavoisier's name stricken from the charter membership of the newly organized Society of Science, when Lavoisier was removed from the Committee on Weights and Measures.

Yet, Cuvier, in his *éloge de Fourcroy* wrote with emphasis and authority, "If painstaking studies had revealed to us the slightest proof of so horrible an atrocity, no human power could have forced us to sully our lips with his eulogy or compelled us to pronounce his praises. . . ." This is a strong statement from a notable scientist who had no reason to speak an untruth. He was, in fact, a good friend of Mme. Lavoisier. On the basis of this statement, any idea that Fourcroy plotted for, or worked for, the death of Lavoisier can be dismissed.

There remains only the fact that Fourcroy, professed friend of Lavoisier, powerful agent of the Revolution, did not work to *save* this friend. Could he have saved him if he had tried? Robespierre had D'Arcet's name placed on the list of proscripts; Fourcroy had it removed. Chaptal was imprisoned in Montpellier; Fourcroy secured his release through the Committee of Public Safety and had him brought to Paris as an expert in the making of gunpowder and saltpeter. Lavoisier was much more of an expert than Chaptal—but Lavoisier had been a member of the Powder Commission of the old régime. There would have been strong prejudice against placing Lavoisier in such a position. It is likely, however, that Fourcroy could have secured Lavoisier's release to work on weights and measures—and without great danger to his own position—had he done so immediately after Lavoisier's arrest. He made no such move.

As a farmer, Lavoisier was in a much worse position than many of his colleagues of science who fell under suspicion. More than any other single organization in France, perhaps, the farm had stood in the way of reform. Yet, several farmers were snatched from death at the last moment by the intervention of influential friends. One was transferred from the Conciergerie the very day of the execution, and conveniently forgotten. Mollien, though not a farmer, was arrested with them

and expected to meet death with them. He was conveniently left behind when the prisoners were transferred to the Conciergerie. Fourteen farmers were never brought to trial at all because they were able to elude arrest. The methods of Committees and the Tribunal were slipshod; many a man escaped death through error or influence. If Dupin felt that he had the power to transfer Lavoisier to another prison to be conveniently forgotten, Fourcroy certainly had power to engineer a similar scheme; Fourcroy was a much more important figure in the Revolution than Dupin.

Hallé, a former non-juring priest, and Borda, an ex-nobleman, both under suspicion, dared present protests but Fourcroy dared none. The only accusation which can with fairness be hurled at Fourcroy is that of cowardice; he made no apparent effort to save "his friend, the companion of his labors." He accuses himself in his eulogy of Lavoisier, "Go back to those frightful days in which Terror drove men apart, isolated individuals from families, from hearths, in which a word, a mark of solicitude were rated as conspiracies," he said. Guilty in fact? No! Guilty in conscience? Yes!

A century and a half have passed since Lavoisier died on the guillotine. Men have criticized his unethical conduct in science; men have modified his findings, but his great scientific thesis remains unchallenged.

Back along the ever-broadening highway of achievement in chemistry, back at its narrow beginning stands the spirit of Lavoisier, descendant of the king's postillion, lighting the way. Carrying this light forward into the darkness of the unknown, broadening and deepening the pathway is the spirit of modern research. The memory of Antoine Lavoisier is forever lighted by the torch he kindled, the torch which now sheds the warm radiance of science into the abodes of men.

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TORCH AND CRUCIBLE

(continued from front flap)

the great friendship between the Lavoisier and Du Pont families, and the early association which led ultimately to the founding of the great American chemical industry bearing the Du Pont name. This is but one of many instances in which the author deals with important and interesting material neglected by previous writers on Lavoisier. Although Mr. French skilfully explains the scientific contributions of the great chemist—and explains them in non-technical language for the general reader—his emphasis throughout is upon a synthesis of Lavoisier's mind, personality, and remarkable career.

Here is a book which will hold the absorbed attention of all readers and reward them with one of the most vivid and full-bodied biographies of the year.

THE AUTHOR

SIDNEY J. FRENCH has been interested in Lavoisier for many years—at first because of his specific contributions to chemistry, but increasingly because of the personal enigma which he presents and the drama in which he played.

Mr. French was born in Superior, Wisconsin, received the B.S. degree of the University of Chicago, and the M.S. and Ph.D. degrees of the University of Wisconsin. Before his graduation from college he had served as lieutenant of the Intelligence Service during the First World War. His first teaching appointment was at Superior Teachers College, and this was followed by appointments at the University of Wisconsin, Franklin College. and Colgate University—where he has been professor of chemistry since 1938.

He is the author of *The Drama of Chemistry,* published in 1937, and of popular articles in the *Scientific American* and *Coronet,* as well as numerous technical papers in scientific journals.